FIELD OBSERVATIONS OF STRANDED OIL IN THE STRAIT OF MAGELLAN, CHILE 12½ YEARS AFTER THE "METULA" SPILL

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ABSTRACT

This spill of 1.42 M barrels of light Arabian crude in August 1974 was, at the time, the largest oil spill from a tanker and was not contained or dispersed, nor were shoreline cleanup measures implemented. A coastal field survey was carried out in January 1987 to make observations on any remaining stranded oil and to collect samples for subsequent total hydrocarbon and GC analyses. The results would then be compared with the data obtained from the BIOS experiment in Bay 11, where a nearshore release of Lagomedio crude similarly was allowed to strand and degrade naturally. The coasts affected by the "Metula" spill, in the Strait of Magellan, Chile, had been visited previously by one of the authors (EHO) in 1977 and most recently, in February 1981, by Gundlach et al. (1982). On both of those occasions extensive asphalt pavements were observed.

At one sheltered, low-energy location (Puerto Espora, in Tierra del Fuego) considerable amounts of stranded oil remain in the intertidal zone and on the shore above the level of normal wave activity. This oil remains primarily as an asphalt pavement that contains on the order of 50 to 100 m^3 of relatively fresh and unweathered crude and "mousse". This report compares the observations from this site visit to the "Metula" area 12½ years after the spill with those from the BIOS experiment at Bay 11 over a 4-year period (1981 to 1985).

RÉSUMÉ

Le déversement de 1,42 millions de barils de brut léger de l'Arabie en août 1974 était, à l'époque, le plus important déversement de pétrole par un pétrolier. Il n'a été ni confiné ni dispersé, et aucune mesure de nettoyage de la côte n'a été entreprise. Un relevé des côtes a été entrepris en janvier 1987 afin de faire des observations de tout reste de pétrole abandonné et de prélever des échantillons pour le dosage des hydrocarbures totaux et pour les analyses par CPV. Les résultats devaient être comparés avec les données obtenues par les essais BIOS dans la zone Bay 11, où un déversement près du rivage de brut de Lagomedio a été abandonné aux éléments. Les côtes touchées par le déversement du Metula, dans le détroit de Magellan, au Chili, avaient déjà été visitées par l'un des auteurs (EHO) en 1977 et plus récemment, en février 1981, par Gundlach et al. (1982). A ces deux occasions, on avait observé des revêtements de bitume.

Dans un emplacement abrité, soumis à des vagues à faible énergie, (Puerto Espora, Terre de feu), des quantités considérables d'hydrocarbures abandonnés restent dans la zone intertidale et sur la plage au-dessus du niveau de l'activité normale des vagues. On les trouve surtout sous forme de revêtement de bitume contenant environ de 50 à 100 m^3 de pétrole relativement frais et non altéré, et de "mousse". La présente étude compare les observations de cette visite de la zone d'impact du Metula, 12½ ans après le déversement, à celles de l'essai BIOS (Bay 11) faites pendant une période de 4 ans (1981-85).

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1.1 Introduction

This project was conceived during an evaluation of the results of the BIOS (Baffin Island Oil Spill) experimental oil spill. The idea to collect data from the "Metula" spill site developed during discussions on the applicability of the data from this controlled release of oil to real-world spills.

The BIOS project involved a series of studies which included the release in 1981 of 15 m^3 of Lago Medio crude on the water surface adjacent to a pocket gravel beach (referred to as Bay 11), on the shore of Ragged Channel at Cape Hatt, Baffin Island, N.W.T. (72°32'N, 79°50'W). An overview of the BIOS project, including this phase of the shoreline studies, is provided by Sergy and Blackall (1987). Field observations, sample collection and chemical analyses of the samples were carried out at Bay 11 in 1981, 1982, 1983, and 1985 to provide a time-series on the fate and persistence of stranded oil in this arctic coastal environment (Owens et al., 1986a, 1987a, 1987b, 1987c). A significant feature of the change in the character of the stranded oil was the formation of an asphalt pavement that had developed in the intertidal zone of the study beach prior to the 1983 field survey. Similar asphalt pavements had been reported following the "Arrow" spill in eastern Canada (Owens, 1978), the "Amoco Cadiz" spill in northern France (J. Denis, CEDRE, Brest; pers. comm., 1984) and the "Metula" spill in southern Chile (Blount, 1978; Gundlach et al., 1982; Owens, 1978).

A site visit to the "Amoco Cadiz" area in March 1985, 7 years after the spill incident, was funded by Environment Canada to record the character of the asphalt pavements, collect samples for chemical analyses and to compare the data with that from the BIOS project. These observations and results are reported and discussed by Owens and Robson (1985), Hope and Humphrey (1986), and Owens et al. (1986b). One of the authors (EHO) had visited the "Metula" site in January 1977 as part of an Environment Canada project; a

proposal to revisit the area 12½ years after the spill to record the character of the asphalt pavements and to collect samples for chemical analyses was supported by Environment Canada.

The objectives of this study were to:

(1) visit coastal locations where oil was known to have persisted 6½ after the spill (Gundlach et al., 1982);

(2) record the extent and character of any remaining stranded oil, with emphasis on the asphalt pavements;

(3) collect samples for subsequent total hydrocarbon concentration and gas chromotography analyses; and

(4) compare the observations and results of the chemical analyses with those from the BIOS experiment and the "Amoco Cadiz" project.

This report records the site visits and observation made during the field survey (20-23 January 1987). The sample analyses were not included in this phase of the project and will be reported and discussed at a later date.

1.2 Methods

A total of nine sites in the eastern section of the Strait of Magellan (Fig. 1.1) were visited during the field survey. Observations were recorded and photographs taken to describe the character and location of any stranded oil. Samples were collected in plastic bags for total hydrocarbon concentration analysis and in 4 oz. cleaned glass jars for GC analysis.

1.3 Field Programme

The field survey was conducted in January 1987 during the austral summer. Site visits were made as follows:

20 January:	Banco Orange	(5)
	Puerto Espora	(6)
21 January:	Punta Dungeness	(1)
	Daniel Este	(2)
	Canadon Grande	(3)
22 January	Punta Malvinas	(4)
	Rio Oscar	(9)
	Punta Baxa	(8)
23 January	Puerto Espora	(6)
	Bahia Azul	(7)

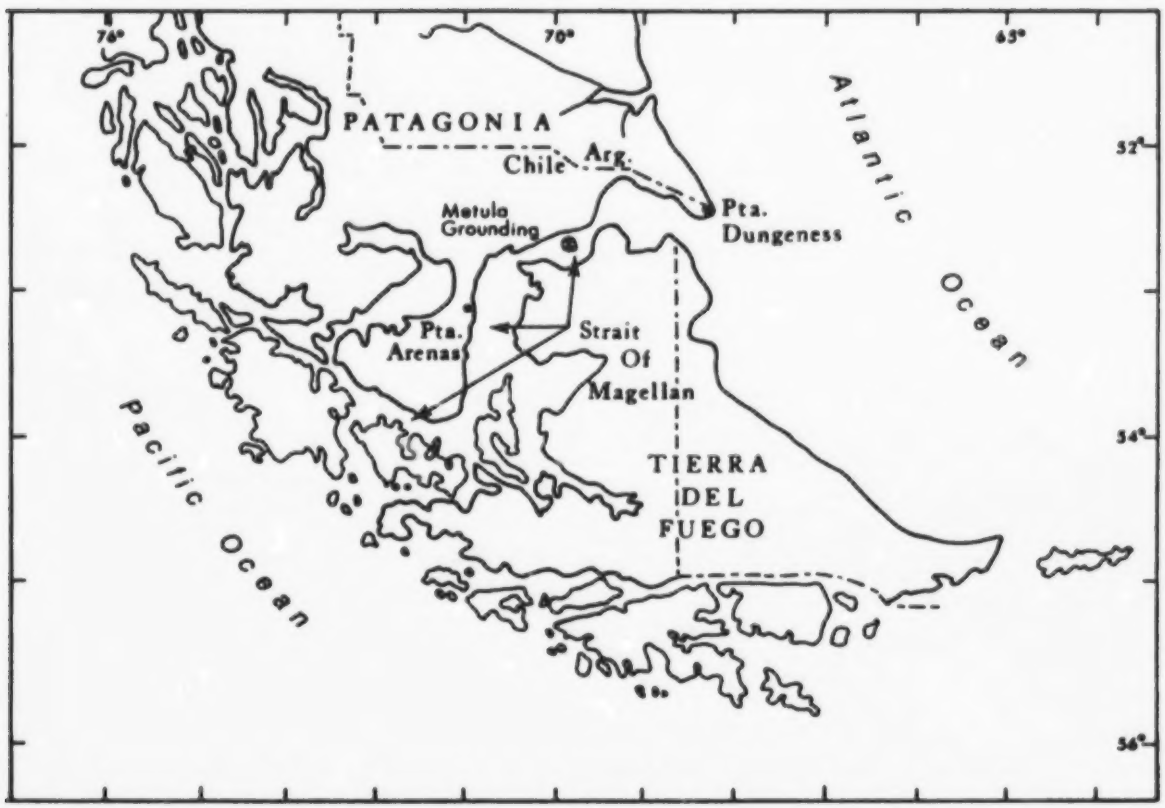

Figure 1.1 Location of the "Metula" spill site (Hayes and Gundlach 1975).

The number in brackets refers to the site locations shown in Figures 1.2 and 1.3. The times and heights of the tides at Punta Delgada during the field programme are given in Table 1.1.

Previous investigators have used a variety of names to describe their study sites and in some cases different names have been used for the same location. The site names used in this report have been taken from Chilean charts 1126 and 1137. Most discrepancies relate to the Espora area: Punta Espora, which was not visited during this survey, is a headland to the west of Bahia Azul. Puerto Espora is a small inlet-spit-marsh system, also known as the west marsh or west creek, at Puerto Progreso just to the east of Bahia Azul (Fig. 1.3). The shoreline locations and site names used in this report do not necessarily coincide with those of previous studies. The site names used in this report are listed in Table 1.2 along with those used by previous investigators who have used different nomenclature. The exact location of each site is described in Section 3.

1.4 Report Format

The history of the spill incident and a brief review of previous studies (Section 2.0) provides a background to the field survey. The results of the site visits are described individually in Section 3.0, with accompanying photographs presented in Appendix C. The observations are discussed in the context of the BIOS data set and the "Amoco Cadiz" survey in Section 4.0.

A complete list of the samples that were collected and the sample logs are given in Appendix A. Sample location sketches and photograph location sketches for the Puerto Espora area are provided in Appendix B. A number of terms and abbreviations that relate to the shore zone used throughout this report are defined in Appendix D.

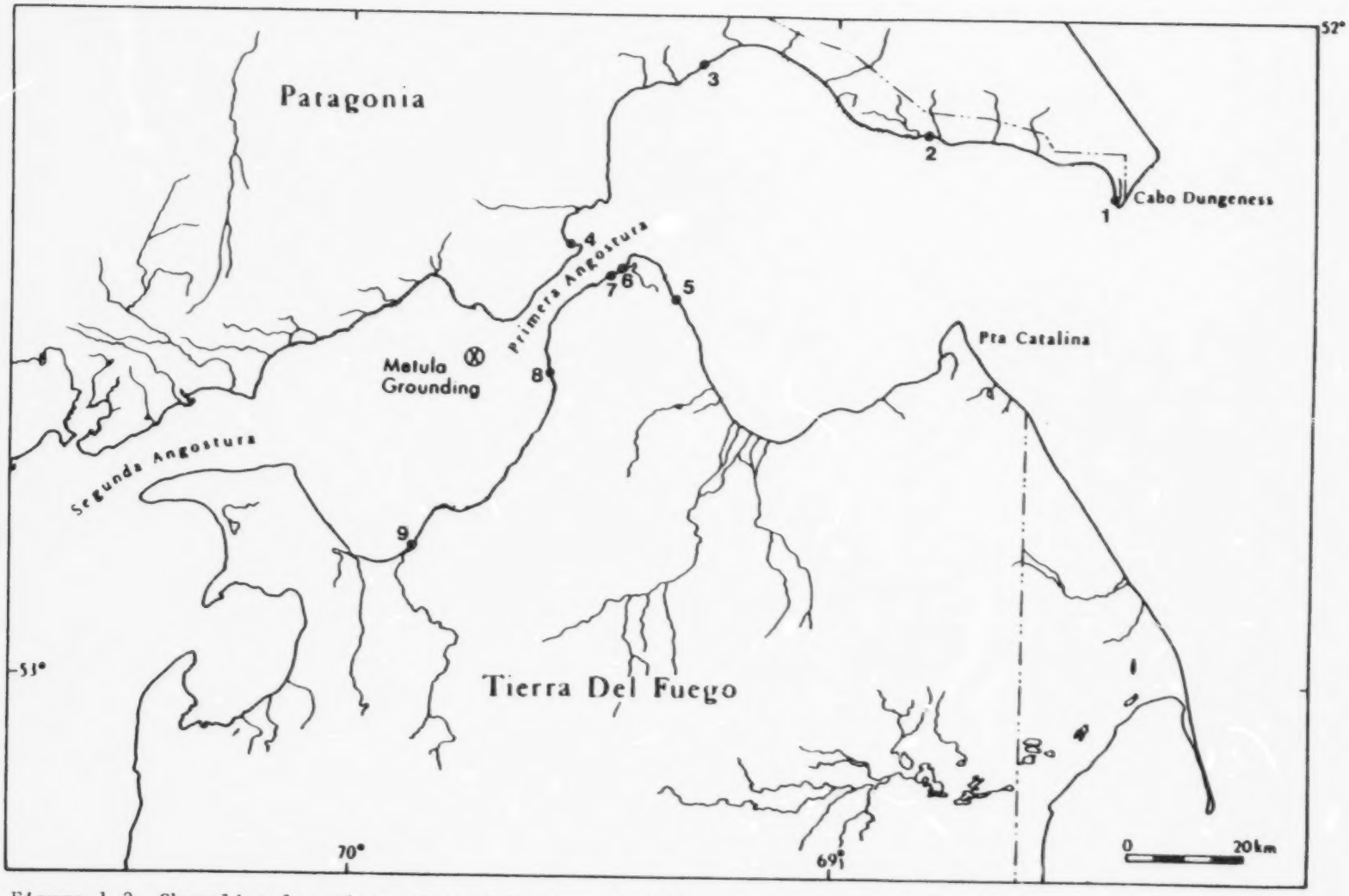

Figure 1.2 Shoreline locations visited in January 1987. The area around the First Narrows (Primera Angostura) is shown in more detail in Figure 1.3.

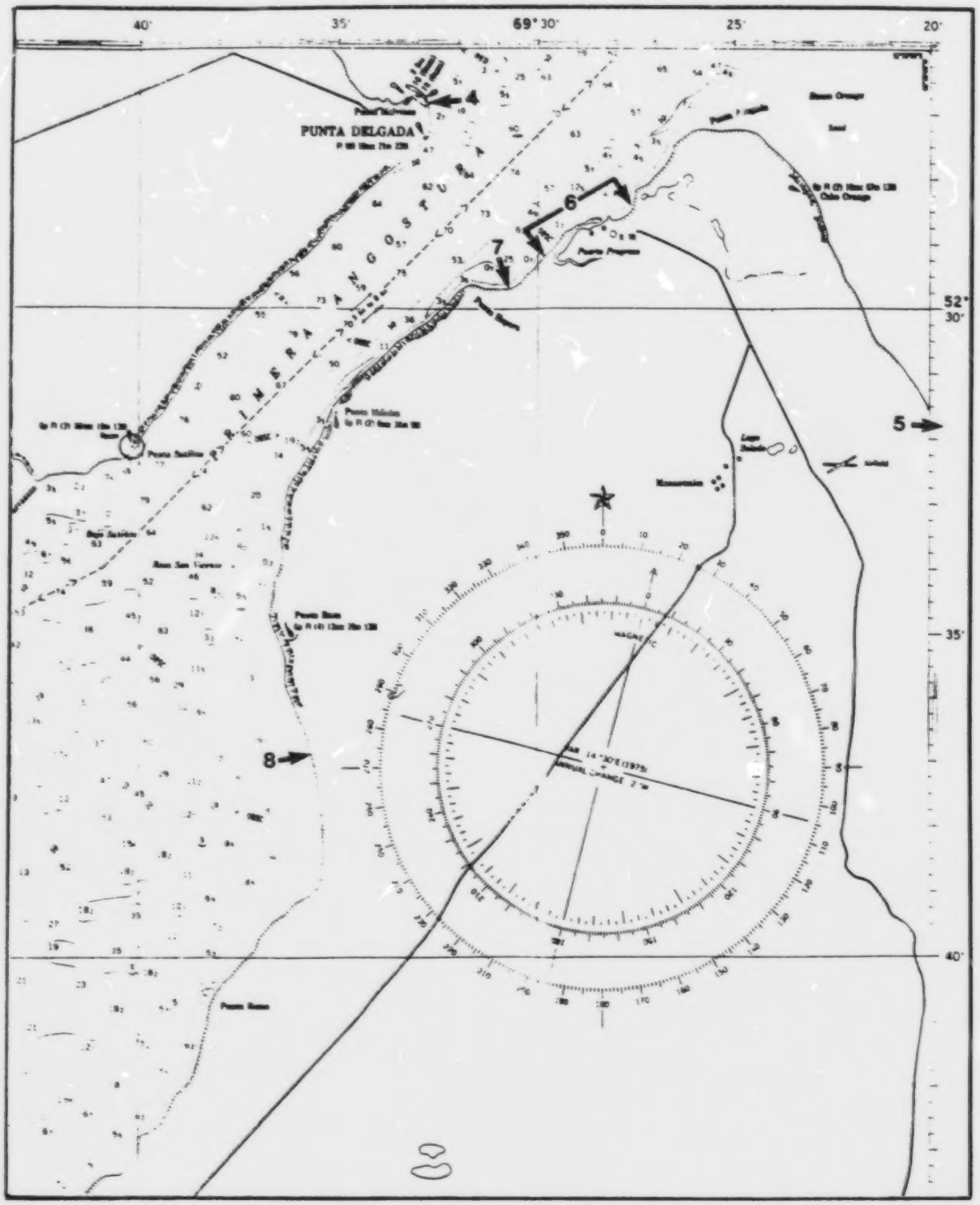

Figure 1.3 Location of sites visited in the area of the First Narrows.

TABLE 1.1 Tide Elevations at Punta Delgada, the First Narrows (Lt. F. Castillo, Capitania de la Puerto de Punta Delgada; pers. comm., 1987)

DATE	TIME	ELEVATION
20-1-87	01:06	7.98 m
	07:36	2.76
	13:12	8.00
	19:48	2.08
21-1-87	01:42	7.98
	08:12	2.75
	13:54	7.86
	20:24	2.32
22-1-87	02:24	7.93
	08:54	2.74
	14:42	7.68
	21:06	2.61
23-1-87	03:12	7.86
	09.48	2.71
	15:42	7.51
	22:00	2.72

TABLE 1.2 List of Field Sites with Alternative Names and Codes used in Earlier Shoreline Studies

SITE	ALTERNATIVE NAME(S)
1. Punta Dungeness	MT-13 (Blount 1978)
2. Daniel Este	near MT-16 (Blount 1978) near Punta Daniel (Gundlach et al.1982) near Deposit B (Hann 1975)
3. Canadon Grande	-
4. Punta Malvinas	Punta Delgada, MT-14 (Blount 1978)
5. Banco Orange	MT-7 (Blount 1978) Cabo Orange (Gundlach et al. 1982)
6. Puerto Espora	West Estuary (Hann 1974) Punta Espora, MT-3 (Blount 1978) Puerto Espora: West Inlet (Guzman and Campodonico 1980) Puerto Espora spit and tidal flat (Gundlach et al. 1982) Puerto Espora, "H" (Straughn 1981)
7. Bahia Azul	Puerto Espora (Hann 1974) Punta Espora, "G" (Straughn 1981) Punta Espora (Gundlach et al. 1982) MT-6 (Blount 1978)
8. Punta Baxa	near MT-2 (Blount 1978) near "E" (Straughn 1981)
9. Rio Oscar	-

2.1 Spill Incident

The VLCC "Metula", en route from the Arabian Gulf to Quintero Bay, Chile, ran aground at full speed during the night of 9 August 1974 on Banco Satelite, just to the west of the First Narrows in the Strait of Magellan, Chile. The vessel carried a cargo of 194,000 tons (approximately 1.42 M barrels) of light Arabian crude. Oil was spilled from the initial grounding and subsequently at intervals until the vessel was refloated on 25 September, as further damage to the hull and tanks was caused by strong tidal currents (up to 9 knots). The oil spill budget for the incident is estimated as follows:

51,500 tons (about 400,000 bbl) of crude oil, and
2,000 tons (about 15,000 bbl) of Bunker C.

Major releases of oil occurred on 11 August, 19 August and 4 September, coincident with spring tides. Most of the oil, about 41,000 tons, was spilled before 22 August, but oil was still visible on the water surface of the Strait as late as 10 October, 1974 (Gunnerson and Peter, 1976).

No attempts were made to contain or disperse the spilled oil on the water, apart from the transfer of oil from the grounded vessel to a smaller tanker, and no shoreline cleanup measures were taken.

High winds, waves, and strong tidal currents spread the spilled oil rapidly, both to the east and to the west of the site, and resulted in the formation of a "mousse". Calculations indicated that the average water content of the emulsion was 30% and that over half of the spilled oil was stranded on the adjacent shorelines (Hann and Young, 1979). A total of approximately 250 km of shoreline were contaminated initially (Blount, 1978). The areas of severest impact were on the south shores of the Strait in the vicinity of the First Narrows (Figs. 2.1, 2.2, and 2.3).

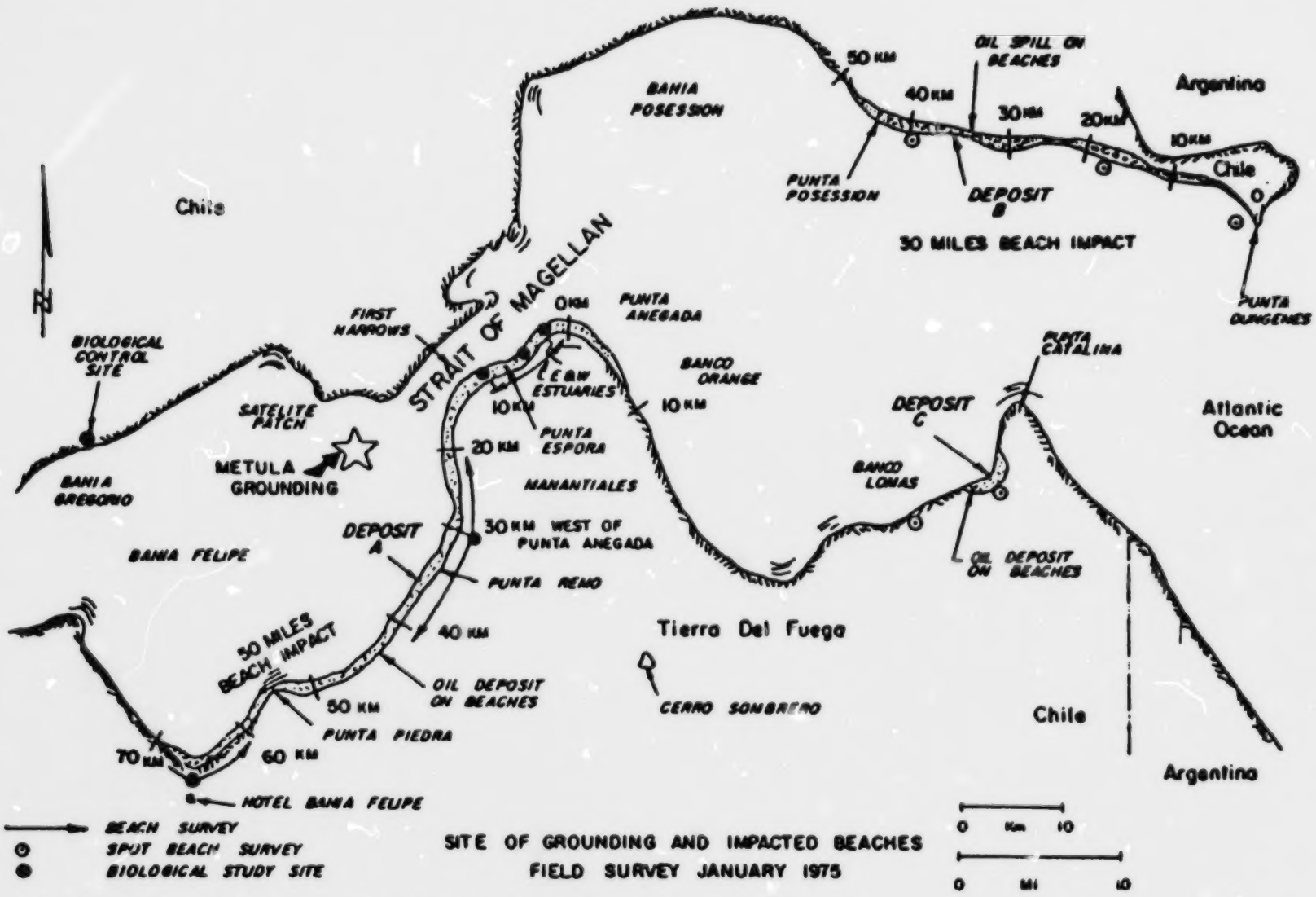

Figure 2.1 Oil distribution, January 1975 (from Hann and Young, 1979).

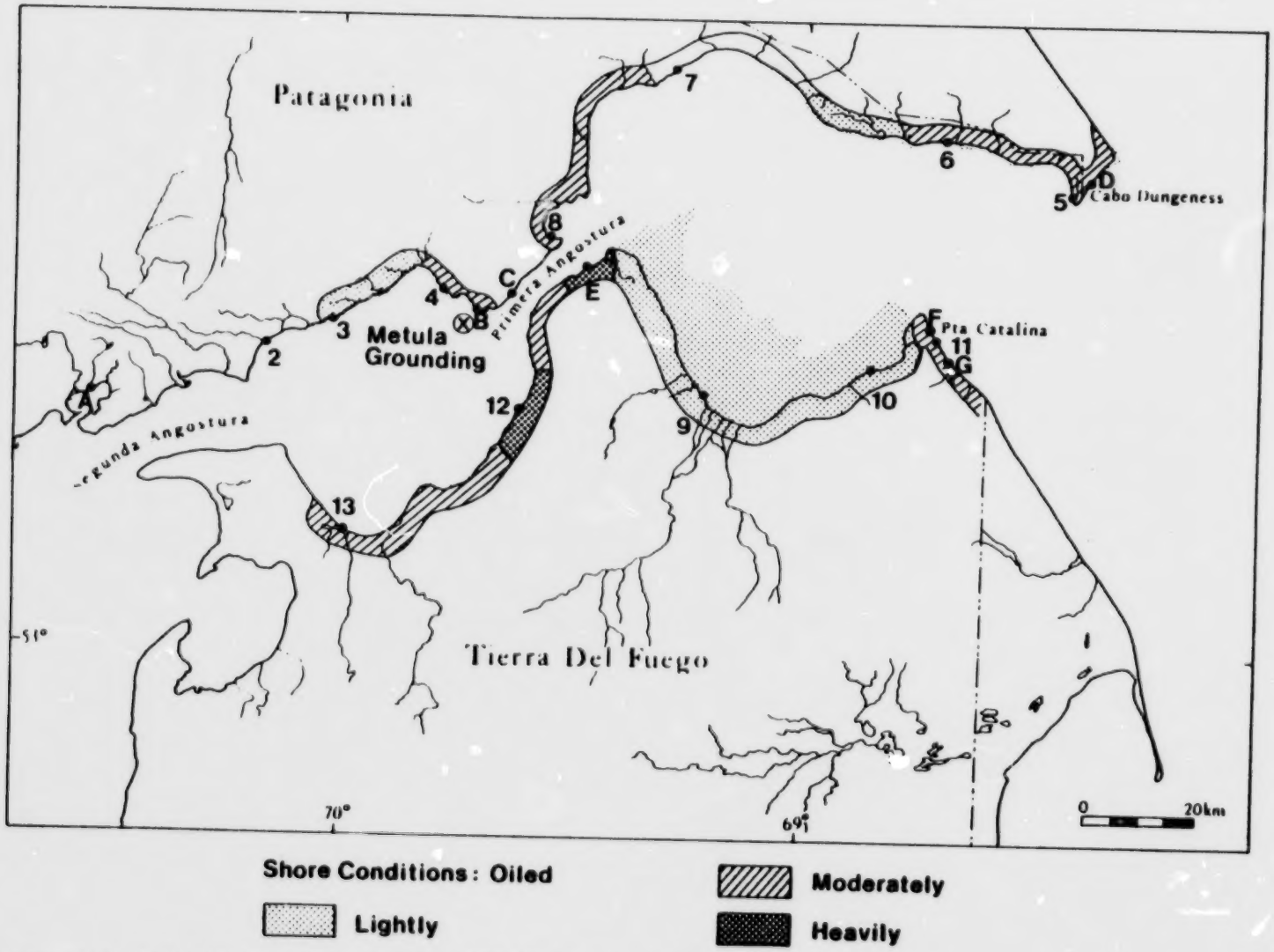

Figure 2.2 Oil distribution, August 1975 (from Hayes and Gundlach, 1975).

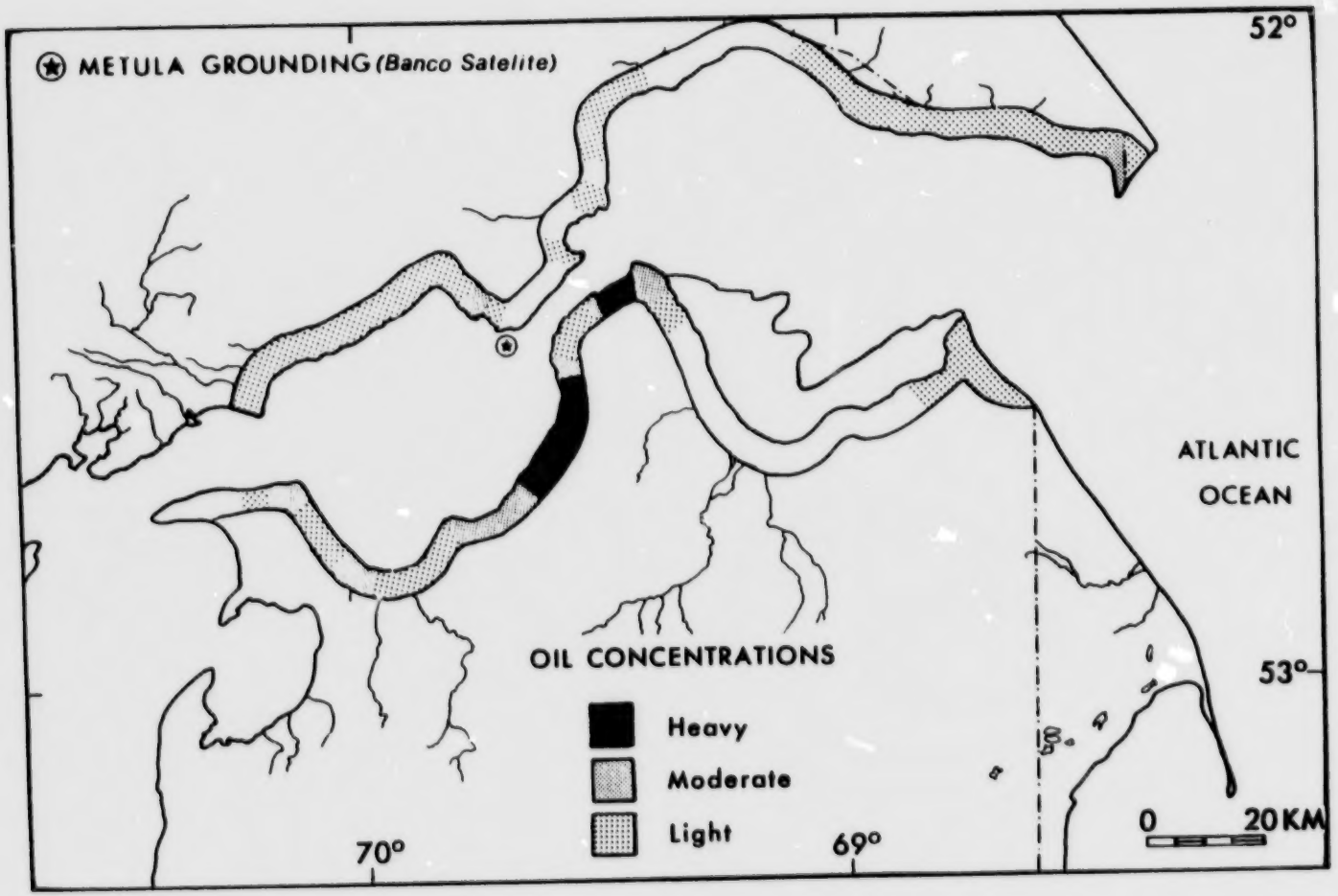

Figure 2.3 Oil distribution, February 1976 (from Blount, 1978).

2.2 Research Activities and Results

A number of surveys of the distribution of oil on the shoreline were conducted between August 1974 and 1981 (Table 2.1). In addition, a variety of other investigations were conducted on the fate and effects of the spilled oil (Table 2.2).

The survey conducted by Hann in January 1975, approximately 6 months after the grounding of the "Metula", indicated that 128 km of shoreline were still contaminated at that time (Fig. 2.1) and that a "moussecrete" had formed at a number of locations (Hann, 1975). One year after the spill, in August 1975, Hayes and Gundlach (1975) reported the presence of an "oil conglomerate" at Punta Espora, Punta Delgado, and Capo Dungeness. Blount (1978) reported the presence of asphalt pavements at more than 10 separate locations in January 1976.

Blount collected sediment samples in 1976 for total hydrocarbon analysis from the asphalt pavements and at other locations. The results of the analyses were presented as a per cent volume of oil. These data have been converted back to oil-in-sediment by weight values (Table 2.3 and Fig. 2.4) in order to make direct comparisons with data sets from the BIOS experiment and from a recent survey of the "Amoco Cadiz" asphalt pavements (Owens et al., 1986b). The samples listed in this table include only those collected from asphalt pavements, as shown on the sketch maps presented by Blount. The results produced mean values of 47,860 mg/kg oil-in-sediment by weight for samples collected from beach-face pavements, 17,600 mg/kg for low-tide terrace pavement samples, and 52,400 mg/kg for backshore pavement samples (Table 2.4).

Blount compared the oil content of sediments with the mean particle size (Fig. 2.5) and concluded that, with the exception of silt or mud tidal flats which rarely contained stranded oil, no direct correlation existed between either grain size and oil content or sorting and oil content.

TABLE 2.1 Shoreline Surveys

(1)	Texas A & M University		
	August	1974	(Hann, 1974)
	January	1975	(Hann, 1975)
	January	1976	(Hann & Young, 1979)
	August	1976	(Hann & Young, 1979)
	January	1977	(Hann & Young, 1979)
	January	1978	(Hann & Young, 1979)
(2)	University of South Carolina/Research Planning Institute		
	August	1975	(Hayes & Gundlach, 1975)
	February	1976	(Blount, 1978)
	August	1976	(Blount, 1978)
	February	1981	(Gundlach et al., 1982)

TABLE 2.2 Related Research Activities (after Hann & Young, 1979)

Principal Investigator(s)	Organisation	Sponsor	Topic Area	Chilean Counterpart
R.W.Hann, Jr.	Texas A&M Univ.	U.S.C.G.	Fate and Effect Co-ordination	Instituto de la Patagonia
R.R.Colwell	Univ. of Maryland	N.S.F.	Microbial Degradation	Catholic Univ. of Valparaiso
J.Emerick	NOAA	NOAA	Vegetation	Instituto de la Patagonia Univ. of Chile
D.Baumgartner V.Gallardo	EPA	EPA	Sub-Tidal Hydrocarbon	University of Concepcion
M.O.Hayes E.R.Gundlach	Univ. of South Carolina	N.S.F.	Beach Geomorphology	Catholic Univ.of Valparaiso
J.Rule	Old Dominion Univ.	N.S.F.	Chemical Degradation	---
J.S.Warner	Batelle N.W. Labs	NOAA	Chemical Analysis of Tissue	---
D.M.Straughn	Univ. of Southern California	NOAA	Intertidal Organisms	Instituto de la Patagonia
J.M.Baker	Field Studies Council Orielton, UK	Shell	Marine Biology	Instituto de la Patagonia
L.Guzman I.Campodonico	Instituto de la Patagonia	Local Gov't & Shell	Intertidal Biology	-----
O.Dollenz B. E.Pisano V.	Instituto de la Patagonia	Local Gov't & Shell	Oiled Vegetation	-----
C.Venegas	Instituto de la Patagonia	Local Gov't & Shell	Penguin Population & Bird Repopulation	-----
J. Albaiges F. Casado J. Grimalt	CID-CSIC, University of Barcelona		Hydrocarbon Chemistry	Instituto de la Patagonia (L.Guzman)

TABLE 2.3 Total Hydrocarbon Analyses Results from Asphalt Pavement Samples Collected in 1976 (from Blount, 1978). The original volume data (%) have been converted to oil-in-sediment by weight values (mg/kg). Stations are located on Figure 2.4.

STATION (Station Code)	SAMPLE NUMBER	OIL CONTENT OF SHORE-ZONE ASPHALT PAVEMENT SAMPLES					
		Low-tide Terrace		Beach Face		Supra-tidal	
		%	mg/kg	%	mg/kg	%	mg/kg
Punta Remo	1-1					5.92	19,400
(MT-1)	1-3					8.44	28,420
	1-6					16.24	59,780
	1-8					4.97	16,125
	1-10					1.07	3,335
	1-X					8.47	27,535
Punta Baxa	2-5	9.94	34,030				
(MT-2)	2-Y			19.56	74,975		
Punta Espora	3-6			7.59	25,325		
(MT-3)	3-8			12.22	42,925		
	3-9			7.36	24,495		
	3-16			7.12	23,635		
	3-19	3.31	10,555				
	3-21			7.18	23,850		
	3-23			2.42	7,645		
	3-24			1.37	4,275		
	3-B	10.40	35,790				
	3-C	3.03	9,635				
	3-E			7.97	26,700		
Punta Anegada	4-1					16.18	59,520
(MT-4)	4-3					5.76	18,850
	4-4					29.65	129,950
	4-5					17.68	66,220
	4-6			3.19	10,160		
	4-7			5.54	18,085		
	4-8			6.31	20,765		
	4-9	6.88	22,780				
	4-10					9.41	32,030
	4-11			19.81	76,170		
	4-13					5.75	18,810
	4-14					4.96	16,090
	4-16	1.83	5,750				
	4-17	0.83	2,580				
	4-18	4.14	13,315				
	4-C	7.97	26,700				
	4-X			9.01	30,530		
	4-Y			4.02	12,915		
	4-Z					51.47	327,010
Banco Orange	5-2			39.40	200,470		
(MT-5)	5-3			18.15	68,370		
	5-8			25.79	107,155		
	5-B			2.81	8,915		
	5-C			21.68	85,350		
Bahia Azul	6-1	4.59	14,835				
(MT-6)							
Banco Orange	7-1			5.81	19,020		
(MT-7)	7-2			7.42	24,710		
	7-4			7.07	23,460		
	7-5			3.39	10,820		
Punta Catalina	8-4					6.01	19,720
(MT-8)	8-5					6.92	22,925
Bahia Felipe	10-1			10.05	34,450		
(MT-10)							
Banco Lomas	11-2			21.36	83,750		
(MT-11)	11-3			12.63	44,570		
	11-4			17.82	66,860		
	11-6			21.22	83,050		
	11-A			29.17	126,980		
Punta Dungeness	13-1			19.20	73,270		
(MT-13)	13-3					7.47	24,890

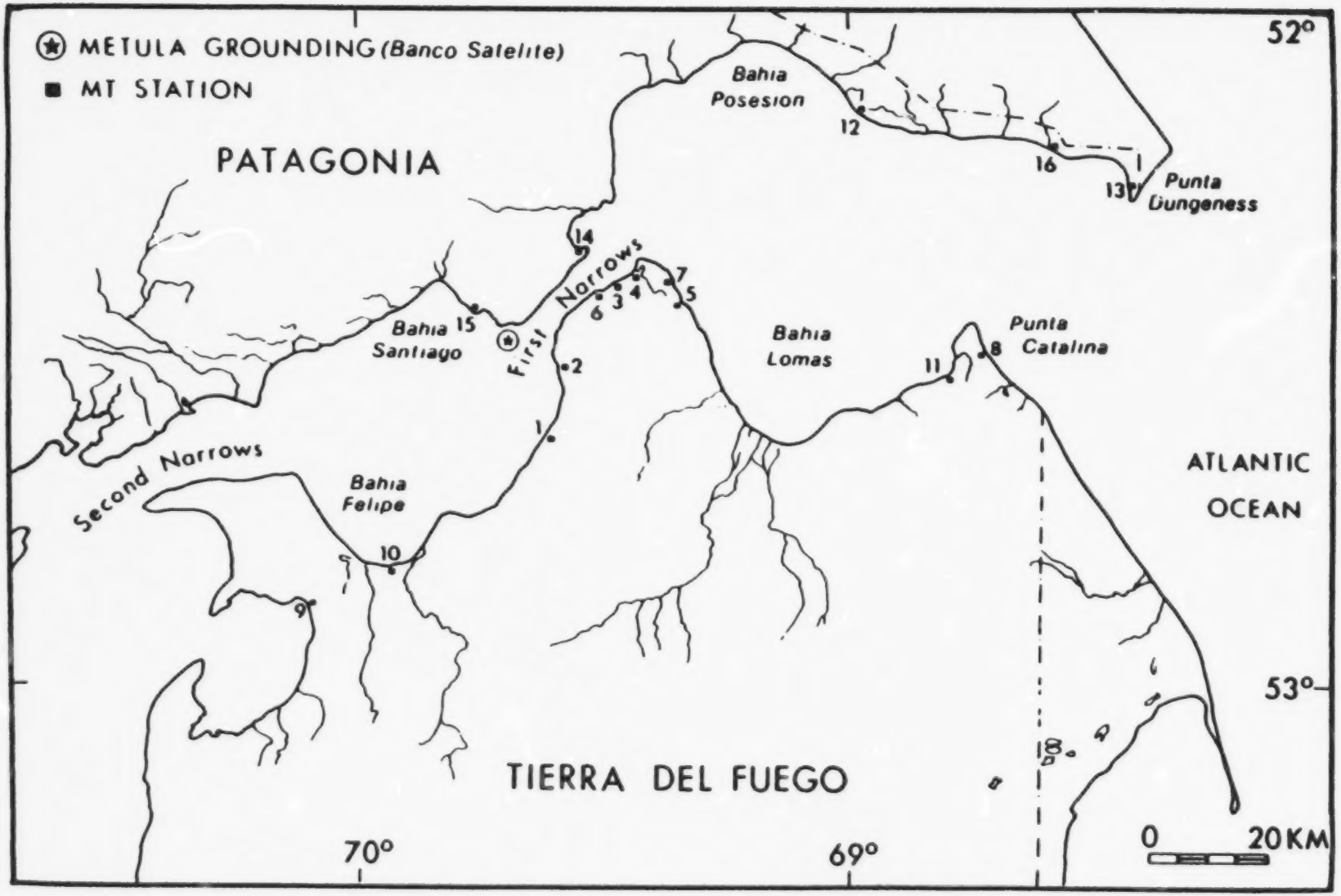

Figure 2.4 Location of Blount's shoreline sample stations (from Blount 1978).

Table 2.4 Summary of 1976 Asphalt Pavement Total Hydrocarbon Data (mg/kg) (derived from Blount, 1978)

	n	mean	range
low-tide terrace	10	17,600	2,580 - 35,790
beach face	31	47,360	4,275 - 200,470
backshore (+mhw)	17	52,400	3,335 - 327,010

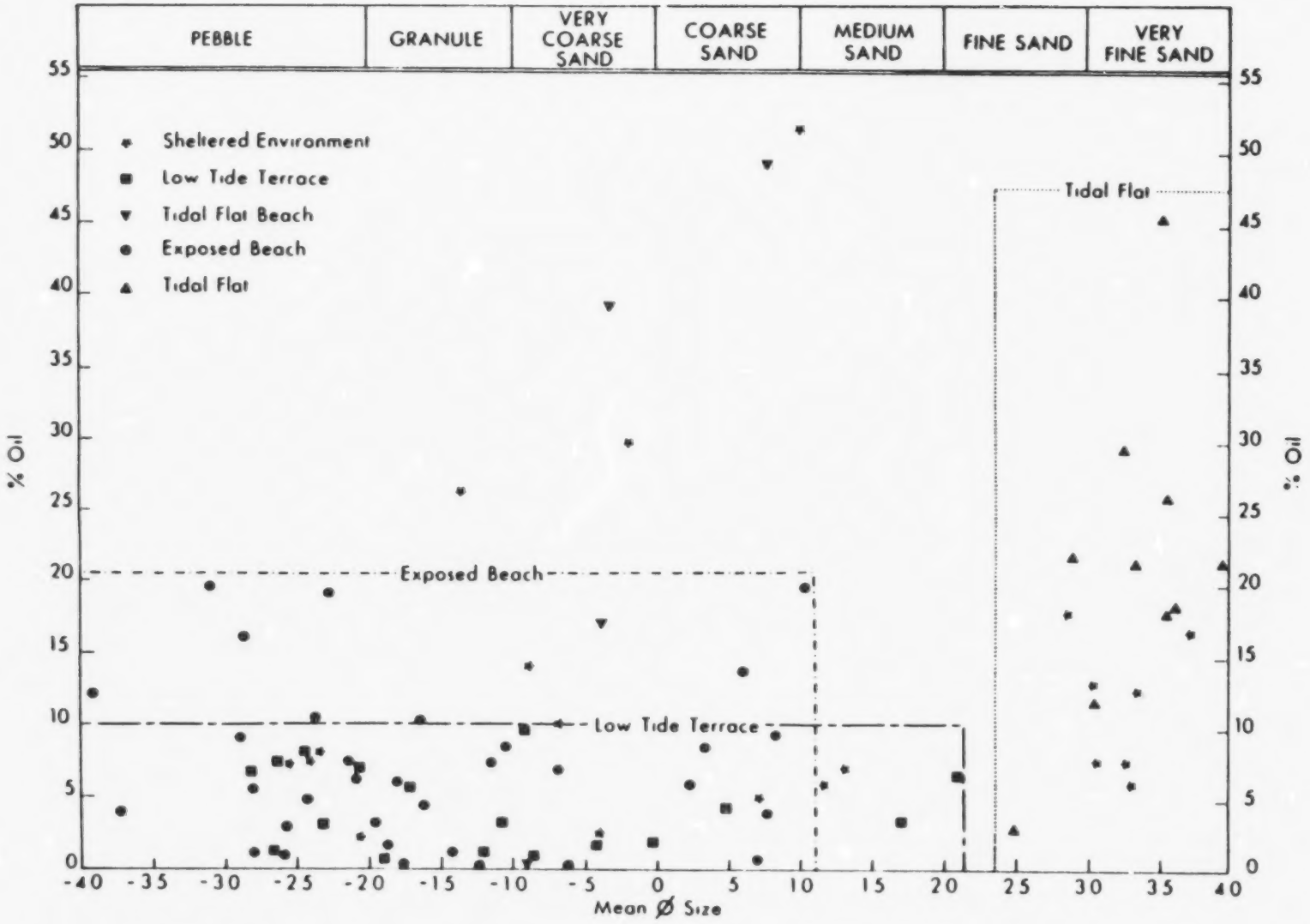

Figure 2.5 Graph of oil content versus mean grain size (from Blount, 1978).

The most recent shoreline survey, by Gundlach et al. (1982) presents observations on the distribution of oil remaining after 6½ years. At that time asphalt pavements were identified at Bahia Felipe, Punta Baxa, Punta Espora, Espora marsh and Banco Lomas. The largest pavement, on a low-tide terrace at Punta Espora, was on the order of90 to 100-m wide and 15-cm thick.

2.3 Environmental Background

The climate of the region is significant in terms of comparisons with other data sets. The mean monthly air temperatures range from +2.5°C in July to a maximum of 11.7°C in January (Gunnerson and Peter, 1976). Despite the relative low latitude location (53°S), this is a cold environment, but the shore-zone environment is not affected by severe freezing.

Strong westerly winds are characteristic throughout the year. Velocities are commonly greater than 50 km/hr and frequently greater than 100 km/hr, with 70% in the directional quadrant from northwest to southwest (Gunnerson and Peter, 1976; Blount, 1978).

The tides are semi-diurnal and the mean tidal range exceeds 8 m near the location of the "Metula" grounding (Table 2.5). Major releases of oil from the stranded vessel occurred on 19 August and 4 September as strong currents associated with spring tides caused the rupture of further tanks. A large proportion of the spilled oil was stranded or redistributed by spring tides over the period 19 to 22 August, at which time the highest predicted high-water levels at Banco Direccion were +14 m, and again between 4 and 6 September (Blount, 1978). Oil was, therefore, stranded above the limits of normal wave activity at many locations (Owens, 1978).

Table 2.5 Tidal Ranges in the Strait of Magellan (from Gunnerson and Peter, 1976)

	Mean Range	Spring Range
Punta Catalina	6.9 m	8.7 m
Punta Dungeness	7.3	9.1
Bahia Posesion	8.4	10.2
Banco Direccion	8.5	10.4
Bahia Santiago	4.3	5.4
Bahia Felipe	3.7	4.6
Second Narrows	4.9	6.2
Punta Arenas	1.2	1.5

Punta Arenas is located on Figure 1.1. All other stations are shown on Figure 2.4: Banco Direccion is marked on that figure by a cross near the First Narrows.

3.1 Punta Dungeness

This large depositional foreland is located at the east end of the Strait of Magellan, approximately 90 km from the spill site (Site 1 on Fig. 1.2). The west-facing beach is very steep, at or near the angle of repose for the well-sorted intertidal pebble sediments. The site was characterized by a series of pebble-cobble storm ridges above the mean high-water level, a high-angle pebble beach-face slope approximately 1.5 m high and 1 m wide, and a low-angle pebble beach-face slope that is up to 100 m wide at low tide. This shore is exposed to waves generated over a 70 km fetch that is parallel to the prevailing and dominant strong westerly winds.

In August 1976, 2 years after the spill, Blount recorded the presence of a double pavement on the upper beach-face slope just below the berm crest (Sample 13-1; Table 2.3) and this pavement appeared to be continuous on the landward side of the berm in the backshore runnel. Fragments of pavement, apparently eroded from the beach face, were scattered over the berm. On the landward side of the runnel a wide, but discontinuous, 2- to 3-cm thick hard asphalt pavement extended 10 to 15 m inland (Sample 13-3; Table 2.3).

No pavement was evident at the time of a site visit in January 1977 (by EHO) and during this field programme a survey along the upper beach and backshore for a distance of about 100 m found no asphalt pavement deposits. Scattered oil patches were evident above the mean high-water level, but these all appeared to be very fresh and were probably deposited very recently. No samples were collected of these oils or oiled sediments. The absence of any pavement at this site most probably is a combination of sediment erosion and burial. This is undoubtedly a very active beach environment that is slowly prograding towards the west as sediment is transported southwards along the Atlantic shore, around the distal point, and then northwards along the study beach. The long-term pattern of net accretion is interrupted by erosion during storm events, which are common, so that the "Metula" oil on the berm was most probably eroded. Storm-wave action would also have been responsible for the burial of any remaining backshore (supratidal) pavement as sediments were deposited above the berm crest.

3.2 Daniel Este

This site is located on the northeast shore of the Strait approximately 80 km east of the spill site (Site 2 on Fig. 1.2). The beach was inspected near the ENAP 85-6 production facility and in the same approximate area as Hann's "Deposit B", Blount's MT-16 station, and Gundlach et al.'s Punta Daniel. At the time of this survey the beach was characterized by a wide (50m), low-angle, intertidal beach-face slope, that gave way landward to a 20-m wide berm above the mean high-water level and to a 5-m high dune ridge. Sediments were in the sand-pebble range, with scattered cobbles above the mean high water.

Blount's surveys in March and August 1976 on this coast indicated the presence of an asphalt pavements on the upper beach face and on the low-tide terrace. In addition, tarballs and pavement fragments were present on the backbeach. She attributed the source to operational spills from the ENAP (the national oil company of Chile) activities in the adjacent backshore area. Gundlach et al. (1982) record a "scattered oil crust" along the upper berm area and "lightly scattered, oiled-sediment conglomerates on the upper low-tide terrace" for observations during 1975/76 at their Station 57 at Punta Daniel. In February 1981, Gundlach et al. report "no oil is present" at this location.

The beach visited during this study may not have been at the same location as described by Blount and by Gundlach et al. (in fact, it is not clear whether Blount's MT-16 is at the same location as Gundlach et al.'s Station 57), as the continuing exploration and production activities of ENAP in this area have caused considerable changes to the network of local access roads. Although the site that was visited in this project was adjacent to a recent ENAP production facility there was no evidence of spills from these activities and a 4- to 5-m high artificial sand berm separated the facility from the shore zone. A small (5-m long by 0.5-m wide), soft asphalt pavement was found in the vicinity of the spring high-water level at the base of the dune ridge. Samples were collected for GC (#15) and total

hydrocarbon (#36) analyses. This pavement was fresh in appearance and, at the time, reservations were made that this may not have been "Metula" oil. Although the possibility exists that the oil could well have come from local ENAP activities, the subsequent observation of several soft, "fresh" sandy oil pavements elsewhere away from the exploration and production activities suggests that the source is ambiguous and should be considered after the samples have been characterized chemically.

3.3 Canadon Grande

This site is on the north coast of the Bahia Posesion (Site 3 on Fig. 1.2). The sand-pebble beach has a wide beach-face slope that gives way to a sand-pebble-cobble berm above the mean high water. The beach is backed by an eroding till cliff that is up to 20 m in height.

According to Hayes and Gundlach (1975), this section of coast was not oiled in August 1975 and further observations by Blount also note the absence of oil in February 1976. No oil was found during this site visit.

3.4 Punta Malvinas

This spit system has grown northwards and westwards from Punta Delgada as a result of the accumulation of sediments carried alongshore by waves travelling from west to east through the First Narrows (Site 4 on Figs. 1.2 and 1.3). The sediments then have been redistributed by waves generated in the Bahia Posesion - Bahia Lomas area of the Strait and by Atlantic swell waves. The spit is characterized by a sequence of relict recurved beach ridges that have become inactive as new ridges have developed to seaward (see Figure 20 in Blount, 1978). The low areas between the relict ridges are occasionally inundated during periods of spring tides and/or storm surges, as evidenced by the presence of relatively continuous lines of undecayed seaweed on the upper beach-face slope. The "beaches" of the sand-pebble relict ridges are at a low angle, have scattered patches of

vegetation and are not subject to wave action at the present. The surface sediment layer is predominantly pebble-cobble, resting on sand-pebble. The ridge crests are characterized by low cedar shrubs (Photo 1; Appendix C).

This section of coast was subject to moderate levels of contamination by August 1975 (Hayes and Gundlach, 1975) and Blount records the presence of oil and pavement along several of the upper fringes of the relict beaches (Fig. 3.1). ENAP activities in this area have resulted in considerable local contamination and several recent operational spills were evident at the time of our site visit. This contamination was, however, largely restricted to the landward margins of the spit system (labelled "heavy pavement" and "oil stain" in Fig. 3.1) and at several locations an asphalt pavement in the upper beach of the relict ridges did not have the same fresh appearance.

Samples were collected at two locations indicated on Figure 3.1. Samples #20, #37 and #38 were taken from a hard pebble-cobble pavement near the spring high-water level. At the site of samples #20 and #38 this pavement was continuous alongshore for about 30 m and was between 1 and 2 m wide. Samples #21 and #39 were taken 1 m landward of #38 at the edge of the vegetation and were from a soft sandy pavement (Photo 1).

3.5 Banco Orange

This exposed beach on the west shore of Bahia Lomas (Site 5 on Figs. 1.2 and 1.3) is characterized by a steep pebble beach-face slope that backs a wide (>500 m) low-tide terrace (Fig. 3.2). The terrace is composed of a wide range of sediments from fine-grained silts to pebbles and cobbles and, at spring low tides, this terrace may be as much as 1500 m wide (Blount, 1978). The beach face is predominantly pebble-cobble sediments with some wind-blown sands present above the mean high-water level.

In February and August 1975, Blount recorded the presence of an asphalt pavement on the landward margin of the low-tide terrace (Fig. 3.2) (Samples 7-2, 7-4, and 7-5 in Table 2.3). At the crest of the beach face some

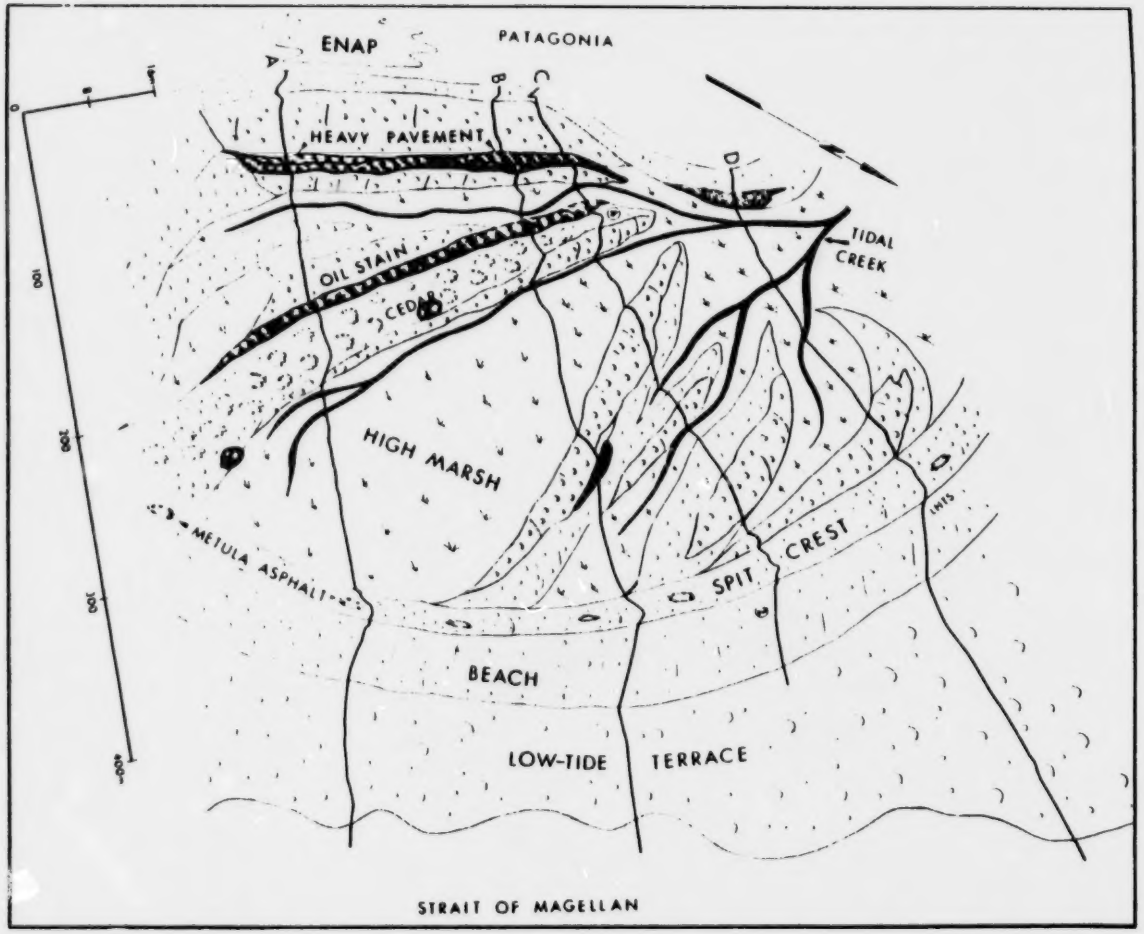

Figure 3.1 Sketch of Punta Malvinas in March, 1976 (Blount, 1978). The two locations sampled during this study are marked by crosses: samples #20 and #37 at left and #21, #38 and #39 at right (arrow).

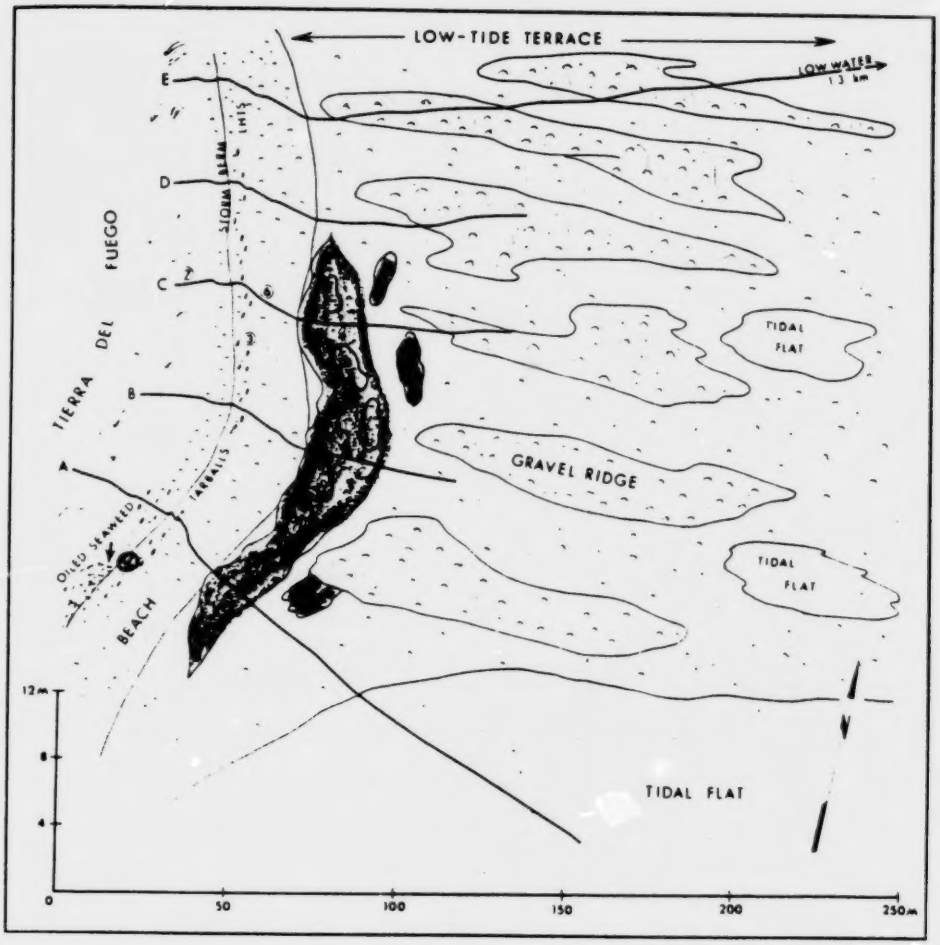

Figure 3.2 Sketch of Banco Orange site in February 1976 (Blount, 1978). The cross marks the location of samples # 1 and # 27 and the arrow sample #2. The outline of the pavement on the low-tide terrace in 1976 has been shaded.

stained pebbles and tarballs were observed. Gundlach et al. report that no surface or buried oil remained along the beach face or the low-tide terrace at this station in 1981. At the time of our site visit oil was found (a) as a buried pavement in the vicinity of the spring high-water level and (b) as particles at the base of the beach-face slope on the inner edge of the low-tide terrace.

The pavement was discontinuous alongshore for approximately 50 m in the section of shore believed to be in the vicinity of Blount's profiles A and B at her MT-7 station. The pavement was soft and sandy in character, contained incorporated shell fragments, varied between 0.5 and 1.0 m in width and was buried on the landward margin by pebble-cobble sediments (Photo 2). Samples were collected for GC (#1) and total-hydrocarbon (#25) analyses (Photo 3).

No evidence of a pavement was found on the low-tide terrace in the area indicated by Blount (see Fig. 3.2). A patch of black particles, 4 m alongshore and 0.5 m wide, was found at one location on the landward margin of the terrace, immediately adjacent to the junction with the beach-face slope. These particles were found to be oily when rubbed between the fingers and a sample (#2) was collected for GC analysis.

3.6 Puerto Espora

This spit system has grown towards the northeast along the southern shore of the First Narrows (Site 6, Figs. 1.2 and 1.3). A tidal creek that drains a small marsh has been deflected approximately 2 km by the spit (Fig. 3.3). The location has be subdivided into five different shoreline environments for this description, each of which is subject to a different range of physical processes and which has remnant oil in differing forms. This area was heavily contaminated by the "Metula" spill and at the time of our visit contained the largest amounts of oil along the coasts that were surveyed. The site was visited on two occasions and 15 of the 24 GC samples and 22 of the 30 total hydrocarbon samples were collected in the Puerto Espora area.

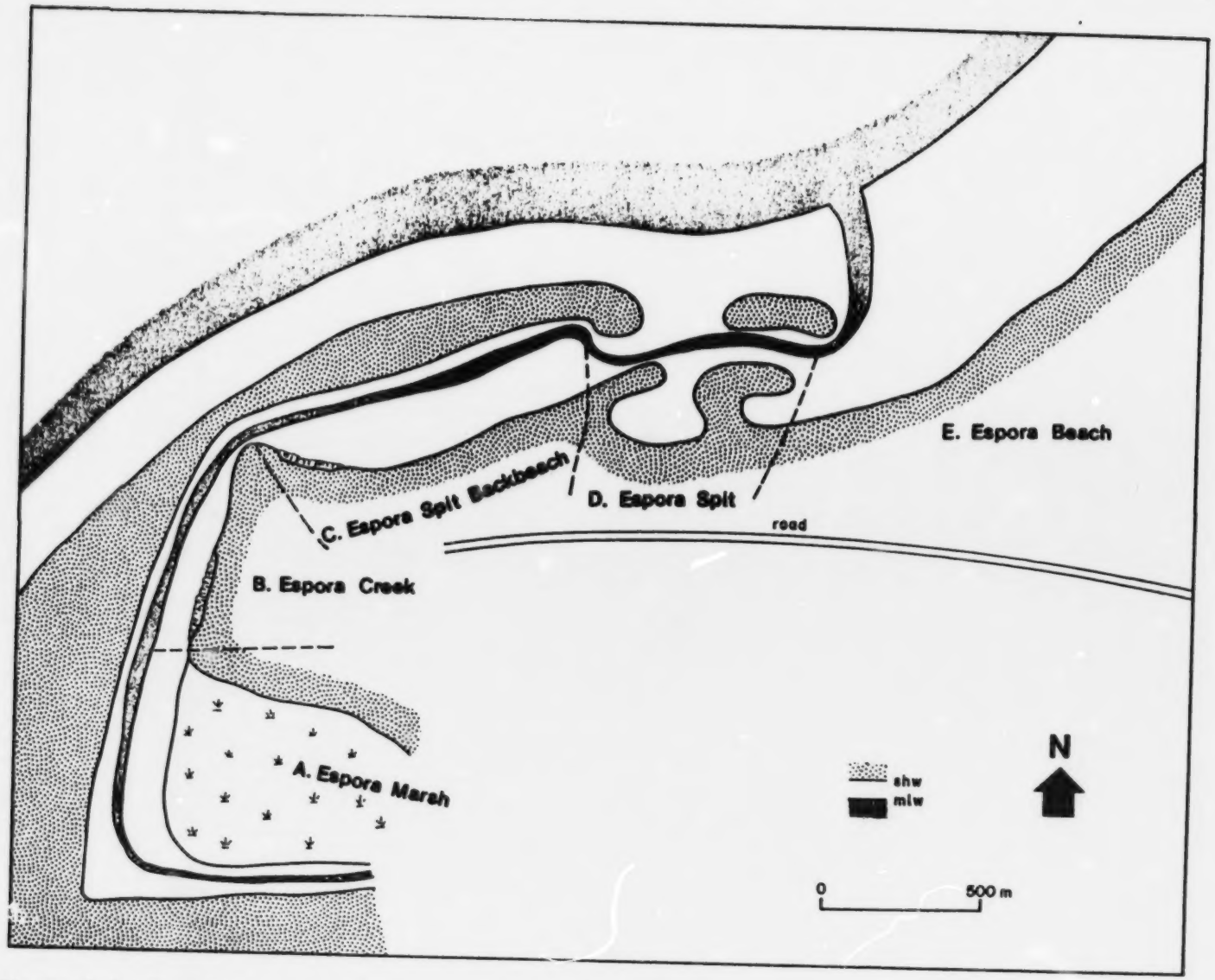

Figure 3.3 Sketch of Puerto Espora area, with limits of the subdivisions used to describe this site.

3.6.1 Espora Marsh (West Estuary)

This small marsh is in the southwest section of the Puerto Espora area and is connected to the ocean by a tidal creek. The marsh was formed by the growth of the spit towards the east which produced a quiescent environment, sheltered from wave activity, within which sediments could accumulate and become stabilized by plant growth. The marsh is a nearly horizontal surface of fine-grained sediments (silts and clays) above the mean high-water level that is vegetated predominantly by Salicornia ambigua. The continuity of the surface vegetation is interrupted by the presence of low (0.5 m) Suaeda argentinensis bushes (Photo 8). The marsh surface is only inundated during periods of spring tides, at times of normal tides the tidal waters are restricted to the single creek that drains behind the spit towards the east.

The marsh was contaminated severely by oil from the "Metula" during periods of spring high tides. The oil was, therefore, carried towards the landward edge of the marsh surface and deposited as a wide (20 to 30 m) band around the rim of the marsh basin. A second area of contamination was the margins of the tidal creek, where oil was deposited by normal high tides. This latter contamination was considerably less extensive than that on the higher marsh surfaces. On the lower sections of the marsh surface the oil flowed over the vegetated surface during the spring high tides but adhered to the higher standing Suaeda (Gundlach et al., 1982). As the tides ebbed, the oil that was trapped by the bushes flowed down onto the marsh surface and smothered the Salicornia. As a result the Suaeda plant and the adjacent Salicornia were killed, leaving an oiled stump and a patch of bare marsh. Examples of this type of contamination were observed in 1977 and were still evident at the time of this visit in 1987 (Photo 7).

The upper sections of the marsh remain heavily contaminated by a continuous but thin (1 to 2 cm) layer of weathered oil (Photos 4 and 5). This surface layer (sample # 3; Photo 6) was covered by a coating of silt-sized sediments and appeared very fresh when the surface crust was removed. No oil was observed on the margins of the creek.

3.6.2 Espora Creek

The south bank of this tidal channel is characterized by mud below the mid-tide level and by a low-angle sand-pebble surface between the mid-tide and spring high-water levels. The spring high-water level is indicated clearly on Photographs 9 and 10 by the thick seaweed deposit. This is a quiescent environment that is affected only by tidal water movement. Waves that are generated would be very small as the fetch area is limited by the dimensions of the channel area.

Oil was deposited across the channel bank above the mid-tide level and by the time of the site visit in 1977 an asphalt pavement had formed. The oil remains in considerable quantities but in a variety of different forms. On the inner sections, nearest the marsh, there is a patchy, soft sand-pebble pavement between the mean and spring high-water levels (Photo 9). To the east this grades into pebble-cobble pavement that is more continuous but is restricted in width to a 10 m band on the upper sections of the slope (Photo 10). Samples were collected from a sandy section (samples # 4 and 26; Photo 11) and from a pebble-cobble section (sample # 27; Photo 12) of this upper intertidal zone pavement.

In addition, there is a narrow (1 to 2 m) asphalt band at the spring high-water level at the base of a low backshore terrestrial scarp (Photos 10 through 16). This asphalt pavement band varies in character from a soft, sandy deposit that can be broken easily by hand to a hard pebble asphalt that can only be sampled by chipping or chiselling. Samples were collected from soft, sandy (sample # 5; Photos 12 and 13), soft, almost solid oil (# 53; Photo 15), hard but malleable sand-pebble (#52; Photo 14), and from very hard pebble-cobble (#54; Photo 16) sections of this band.

3.6.3 Espora Spit Backbeach

The mainland or backbeach section of the spit system is characterized by mud in the lowest sections, below mid-tide level, and by a wide, gently sloping sand, pebble, cobble sediment beach above the mid-tide level. The intertidal zone and backshore are subject to limited wave activity through a

gap in the system at high tides. Nevertheless this remains a very sheltered, low energy environment.

This section of coast was heavily contaminated and within 18 months (by February 1976) Blount reported that an asphalt pavement had formed in the upper half of the intertidal zone and for a distance between 10 and 20 m above the mean high-water level. This section of shore corresponds to the area between Blount's profiles U and E in Figure 3.4. The pavement was continuous alongshore for approximately 700 m and varied in width between 20 and 40 m. By the time of the 1981 survey by Gundlach et al. there had been little apparent change, with "only minor patchy signs of erosion, particularly along the upper edge" of the pavement. A comparison of photographs taken in 1977 and 1987 indicated that the erosion on the landward margin of the pavement (Photo 20) may have been on the order of 1 to 2 m over that 10-year period.

Three views of this beach show the present (1987) extent of the pavement (Photos 17, 18 and 19). The pavement is still virtually continuous, usually between 5 and 10 m wide, though up to 15 m in places, and is generally between 5 and 10 cm thick (Photo 21), but up to a maximum of 20 cm in some areas. The seaward margin coincides with a change in sediment type from sand-pebble to mud. The upper margin is, in most sections, an eroding scarp (Photos 17 through 20), although at the western end it is buried by pebble-cobble sediments (Photos 19 and 24). Where the upper margin is being eroded the edge has a ribbed or serrated character (Photo 22) and occasionally isolated patches have remained as remnants as the surrounding pavement has been eroded.

A trend that was observed in many sections indicated a distinction between a hard, pebble asphalt pavement in the higher sections and a more soft, sand or sand-pebble pavement in the middle sections of the beach-face slope. Samples # 13, 14, 28, and 29 (Photo 22) are from hard pavement in the upper sections; samples # 7, 8, 9, 30, and 31 are from the softer and more sandy

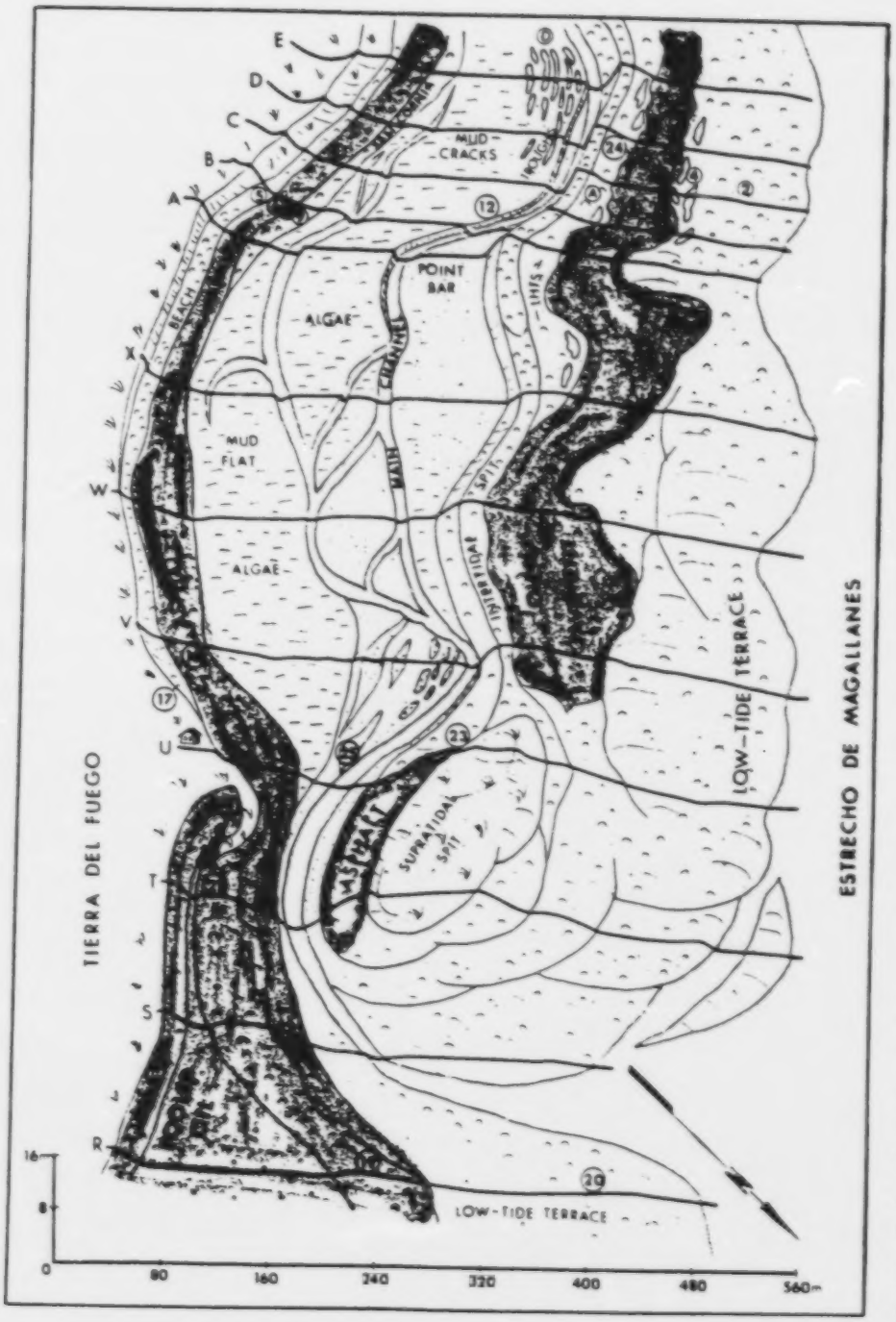

Figure 3.4 Sketch of Espora Spit Backbeach and Espora Spit subdivisions in February, 1976 (Blount, 1978). The areas of asphalt pavement have been shaded.

sections of pavement (c.f. Photo 21). Sample # 8 was collected from the mid-depth interval of a soft sandy pavement, which was broken up by hand and from which a section was rapidly placed into the sample jar. Sample # 9 is the weathered surface crust of the pavement at the same location.

The latex type of crust was observed at a number of locations and was in some instances associated with fresh mousse (Photo 27) but was also found as a hard crust on the surface of the pavement (samples # 6; Photo 25 and # 24; Photo 26). No soft or fresh mousse was found observed on this section of shore. At one location (Photo 23) a "double" pavement was observed which appeared to represent two separate oiling events as the lower section of the pavement was hard and dark in colour whereas the upper half was softer and more brown.

3.6.4 Espora Spit

This relatively short section (150 m) of beach, opposite the distal end of the Espora spit, is treated as a separate unit of the mainland backbeach because the sediments here form two small headland-bay systems, which are unlike the straight beaches to the east and the west (Fig. 3.3). The beach below the mean high-water level has a steep beach-face slope down towards the tidal channel, a wide (40 -50 m) mean to spring high-water section which is characterized by two small embayments, and two small relict spits above the spring high-water level. These two spits were probably formed prior to the migration of the Espora spit to shelter this section of shoreline. The shore is sheltered from incoming wave action by the distal section of the Espora spit.

The beach was heavily oiled by the "Metula" spill and an asphalt pavement was formed in the upper half of the intertidal zone (Fig. 3.4; Blount, 1978). Much of this pavement still remains as a continuous and thick (20 cm) pavement in the upper intertidal zone and above the mean high-water level. The pebble-cobble pavement was generally very hard (Photo 29) and in some sections had been buried, as sediments have been redistributed, or

has been eroded on the upper edge by wave action during periods of spring tides (Photo 28). An area of mousse was found in the easterly of the two small embayments, just below the spring high-water level. This was characterized by a thin (1 cm) weathered crust with a veneer of fines (Sample # 11: Photo 30) overlying a brown mousse (Sample # 10) that was very fresh and that was observed to ooze within a minute of the hole being cut for the sample.

3.6.5 Espora Beach

This beach is an exposed shore that is characterized by a steep pebble-cobble beach face (Photos 31 and 32) and a wide (500 m) low-tide terrace, characterized by silt-mud sediments and low pebble-cobble ridges (Photos 39 and 43). This is not a high-energy wave environment as the open fetch is to the north and northeast, which is a secondary wind direction as only 21% of the winds approach from this quadrant and these are generally light when compared to the predominant westerly winds (Hayes and Gundlach, 1975).

Although this beach is largely outside of Blount's study section (Fig. 3.4) she indicates that the beach face was heavily oiled in February 1976. At the time of this survey oil was found as a continuous asphalt pavement on the beach face in the western half of the beach and as a discontinuous cover on the low-tide terrace. No oil was found on the berm or at the spring high-water level.

The beach-face pavement extended continuously for a distance of between 500 and 750 m from the point indicated by the person on Photograph 32 to the extreme west end of the beach (Photo 31). The eastern-most section of pavement was about 25 m wide and was in the middle to lower portion of the beach-face slope, immediately landward of the low-tide terrace, and was partially covered by algal growth (Photo 33). Sample # 49 was collected from this area (Photo 32) and was a soft sand-pebble mousse which appeared very fresh. The elevation of the pavement increased gradually towards the west so that at the western extremity the upper edge coincided with the mean high-water level (Photo 31). The upper margin of the pavement was very

broken and ribbed in most sections (Photos 34 and 38), as a result of wave backwash action undercutting and eroding the exposed edges. Samples # 12, 34, and 35 were collected at this location from a hard section of sand-pebble pavement on the upper beach-face slope which appeared fresh when exposed. Samples # 50 and 51 were collected nearby, but lower in elevation on the mid-section of the beach-face slope (Photos 35, 36 and 37). These samples, from a soft sand-cobble pavement, were of a light brown mousse with a dark weathered surface crust. On one section which was undergoing erosion at the upper margin (Phot 38), one sample was collected from the soft, sand-pebble, mousse pavement (# 32) and a second (# 33) from the adjacent unconsolidated sediments to determine if these contained measureable concentrations of eroded hydrocarbons. At the majority of locations examined on this beach-face pavement the subsurface oil was a brown or light brown mousse, usually soft and very fresh, and in some cases oozed from the pavement after a sample had been dug.

The low-tide terrace contained considerable amounts of soft mousse-like oil (Photo 42). The oil distribution, expressed as a surface cover, was on the order of 30 to 40% and was generally associated with the gravel ridges rather than with the intervening low-lying wet mud sections. The ridges were characterized by pebble-cobble sediments and thick concentrations of mussels (Photos 41 and 43). A sequence of samples were taken on the inner section of the terrace on a line perpendicular to the shore (see Fig. B.4). Samples # 22, 23, 43, 44, 47, and 48 were from fine-grained or pebble-cobble mousse pavement (Photos 40, 41 and 42), whereas # 45 and 46 were from hard pebble-cobble pavement sections. Sample #44 was taken from a section which had a latex-type crust on the surface of the mousse.

3.7 Bahia Azul

This wide pebble-cobble beach is on the south shore of the First Narrows, immediately to the west of Puerto Espora and to the east of the Punta Espora (Site 7; Figs. 1.2 and 1.3). The intertidal zone is a 100-m wide beach-face slope and gives way landward to a narrow berm and to an eroding till cliff. No low-tide terrace is present, but extensive kelp beds are present within 50 m of the low-water line.

Both Blount in 1976 and Gundlach et al. in 1981 reported the presence of intertidal asphalt pavements, but during this survey no oil was observed either in the intertidal zone or on the backshore. It is possible that some pavement may remain, having been buried by an accretionary cycle, but it is also likely that the intertidal pavement has been eroded.

3.8 Punta Baxa

The site is located approximately 5 km south of Punta Baxa on the east shore of Bahia San Felipe (Site 8; Fig. 1.2). The wide sandy beach is characterized by a low angle berm that is on the order of 50 m wide between the mean-high water berm crest and the low dune ridge (Photo 44). This west-facing coast is open to wave generated over a 100 km fetch by the prevailing and dominant westerly winds. The backshore is subject to wave action that is evidently coincident with surges during storm events.

The beach was oiled at a time of equinoctal spring tides and a thick (5 to 10 cm) layer of oil was observed to cover virtually all of the berm in January 1977, 2½ years after event. This oil cover would have been subject to erosion and burial only during periods of spring tides and/or storm surges. At the time of this site visit a hard sand asphalt pavement was found at the spring high water level, just below the dune ridge (samples # 18 and 42). The pavement was continuous alongshore for about 100m and was buried by sand, pebbles and seaweed on the landward margin (Photo 45). The exposed pavement ranged in width between 0.5 and 1.0 m. At one location the dune scarp had been eroded recently and clumps of small cedar bushes, covered by a layer of weathered oil, had fallen onto the pavement. The oil from the surface of one bush was sampled (#19).

3.9 Rio Oscar

This beach on the south shore of Bahia Felipe (Site 9; Fig. 1.2) is more sheltered from the west than the Punta Baxa site and has a beach that is characterized by a higher proportion of pebbles in the surface sediments. The berm is between 20 and 40 m in width and is backed by a low (2-3 m) dune ridge.

Blount recorded the presence of a pavement in March and August 1976 on the berm at a site farther to the west on this shore. By 1981 Gundlach *et al.* reported that no oil remained on this beach. At the time of this survey a hard sand-pebble pavement was found at the spring high-water level at the base of the dune ridge. The pavement was continuous alongshore for more than 50 m and was buried on the landward side by sand (Photo 46). Samples were collected from a hard, brown sandy section (# 16 and 40) and from a sand-pebble section (# 17 and 41) of pavement.

The field site visits were not intended to cover the entire area affected by the "Metula" oil spill and, therefore, do not constitute a systematic or complete coastal survey. Although it is not possible to define the overall distribution of oil remaining from the "Metula" spill, it is clear that at a few locations the oil remains in significant volumes and is relatively unweathered. With the exception of the Puerto Espora area, oil was found only on the highest sections of the shoreline, in the vicinity of the spring high-water levels. At Puerto Espora the oil is present (1) in very large volumes, probably on the order of $100m^3$ in total, (2) over the entire area, (3) in all sections of the beach from the low-water level to the spring high-water level, and (4) generally as a fresh deposit below the weathered surface crust.

Since 1977, the open beaches that were revisited have been cleaned by marine action up to the base of the dunes. At all of these locations, except Punta Dungeness, only a narrow pavement remains at the highest level of the beach and this is generally buried on the landward margin with only a small section exposed to wave action during periods of high water levels. At Punta Dungeness no pavement was found at the location where it was observed in 1977. In the sheltered sections of the Puerto Espora area, the oil remains in the same locations as was observed in 1977. The changes that are evident are small and have resulted from erosion of the landward margin of the pavements on the Backbeach, Spit and Beach sections (C, D and E) due to the action of wave backwash. Comparison of photographs taken in 1977 and 1987 indicates that this erosion is on the order of 1 to 2 m.

The remaining oil is present in a variety of forms that range from fresh, almost fluid and apparently unweathered, mousse and oil to hard pavement that could be sampled only by chiselling off small fragments using a trowel and rock. A summary of the location and of the character of the samples is given in Tables A.1 and A.2 and is partly summarized in Table 4.1. Although

TABLE 4.1 Summary of Stranded Oil Locations and Environmental Factors

Site	Location of Stranded Oil				Wave-Energy Environment	Sediment Type(s)
	ltt	bfs	m-shw	+shw		
1	-	-	-	-	high	pb: pb/cb
2	-	-	-	x	high	sd/pb
3	-	-	-	-	moderate	sd/pb
4	-	-	-	x	quiescent	sd/pb
5	?	-	-	x	mod-high	pb
6A	-	-	x	x	quiescent	fines
6B	-	x	x	x	quiescent	sd/pb
6C	-	x	x	-	quiescent	sd,pb,cb
6D	-	x	x	x	v. low	fines
6E	x	x	x	-	moderate	fines:pb/cb
7	-	-	-	-	mod-high	pb/cb
8	-	-	-	x	high	sd,pb
9	-	-	-	-	high	sd,pb

the results of the chemical analyses will provide further information on the character of the oils, one observation on the physical nature of the pavements may be significant. A total of 47 samples were collected from asphalt pavements, some of which were described as hard whereas other were soft (Tables A.1 and A.2 in Appendix A): this distinction was based on the observed viscosity of the sample. When the samples are categorized as follows:

sediment type	"soft"	"hard"
sand	17	7
sand-pebble	3	12
pebble-cobble	1	7

an apparent pattern emerges which suggests that there may be a relationship between sediment type (i.e. size) and viscosity. The softer sections of pavement occur predominantly with sands, whereas the hard sections occurred more frequently with coarser (pebble and cobble) sediments.

Other trends which can be detected from the samples are:

(a) 15 of the 24 sand pavement samples were collected at or above the spring high-water level, 9 from the beach face, and 1 from the low-tide terrace;

(b) 22 samples in total were collected at or above the spring high-water level and a further 16 from the beach-face slope, only 4 were from the low-tide terrace and 5 from the berm (between the mean and spring high-water levels);

(c) at the open or high-energy locations (Table 4.1), oil was present only at or above the spring high-water level;

These trends are clearly an artifact of the sampling, but the collection of samples is in part a subjective measure of the distribution and character of the remaining stranded oil. For example, only one site was observed to have oil on the low-tide terrace, whereas oil was present at or above the spring high-water level at 5 of the 9 locations visited.

No one location is exactly similar to the Bay 11 shoreline of the BIOS experiment (Owens et al., 1987a). However, the Espora Beach unit (6E) and the Espora Spit Backbeach unit (6C) are the most analogous and have intertidal asphalt pavements similar to that which formed at Bay 11. Both

are low-energy wave environments with an intertidal beach-face slope of mixed sediments, predominantly in the pebble-cobble range with a secondary sand fraction. Similarities between the Cape Hatt and Puerto Espora pavements include:

a. the presence of a continuous pebble-cobble pavement in the upper intertidal zone on the beach-face slope;
b. evidence of erosion and undercutting on the upper edge of the pavement by the action of wave backwash;
c. the presence of relatively "fresh" oil within the pavement; and
d. sections of "soft" pavement (i.e. the asphalt pavement has a degree of plasticity and could be broken easily by hand but, if walked on, would not be dented nor leave a footprint).

The pavements of the Puerto Espora area have tied up a considerable volume of stranded oil (somewhere on the order of between 50 and 100 m^3). Much of this oil is relatively "fresh" in appearance when exposed by removal of the weathered surface crust. However, the oil is in a semi-stable form as only small amounts appear to be released at any time due to the very slow rate of erosion of the pavement. This erosion occurs primarily along the edges as a result of wave action and most likely produces small particulate hydrocarbon "sediments" which are then transported away from the pavement by normal marine processes (waves and tides). The pavements were not considered to be a major source for potential secondary phase contamination through re-release of oil into the adjacent tidal waters. Even though oil may be release it is thought to be in small quantities and would be have been weathered by physical processes during erosion. Secondary contamination from erosion of the pavements is unlikely to produce serious effects on the local ecosystem, although individual plants or animals could be impacted.

Stranded oil at other locations was restricted to small remnant deposits on the highest sections of beaches. This oil is not considered to be significant in terms of affecting physical or ecological processes at those sites.

In summary, this first phase of of the project has provided a series of qualitative observations on asphalt pavement and remnants of light Arabian crude oil that were stranded 12½ years previously. In some respects the pavements were similar to those observed at Cape Hatt and elsewhere ("Arrow" and "Amoco Cadiz" spills). It is anticipated that the chemical analyses will provide data than can be directly compared to previous studies, in particular the samples from the Espora Spit Backbeach (6C) and Espora Beach (6E) sites are directly analogous to the Cape Hatt experiment in terms of the environmental parameters of the site and the physical character of the pavement.

SECTION 5: ACKNOWLEDGEMENTS

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The general locations of the sample sites are shown on Figures 1.2 and 1.3. Precise sample locations for the Puerto Espora area (Site 6) are given on Figures B.1, B.2 and B.3 in Appendix B. A summary of the samples, in terms of location on the beach, sediment type, and oil type, is given in Tables A.1 and A.2 at the end of this Appendix.

SAMPLE # 1	LOCATION: Banco Orange	SITE: 5	ELEVATION: + shw
Date: 20-1-87	Time: 1650	Surface	Analysis: GC/MS
Cross-Reference Sample:	25	Photos:	2, 3

NOTES: - narrow, sandy, brown asphalt pavement
- some shells and small cobbles
- = Blo"nts's station MT 7 (see Fig. 3.2)

SAMPLE # 2	LOCATION: Banco Orange	SITE: 5	ELEVATION: ltt
Date: 20-1-87	Time: 1655	Surface	Analysis: GC/MS

NOTES: - particulate hydrocarbons at junction of ltt with bfs, on the terrace
- oily on fingers when rubbed
- = Blount's station MT 7 (see Fig. 3.2)

SAMPLE # 3	LOCATION: Espora Marsh	SITE: 6A	ELEVATION: m-shw
Date: 20-1-87	Time: 1800	Surface	Analysis: GC/MS
		Photos:	4, 5, 6

NOTES: - non-vegetated section of marsh flat within one of Straughn's staked quadrants
- latex on fine sediments

SAMPLE # 4	LOCATION: Espora Creek	SITE: 6B	ELEVATION: + shw
Date: 20-1-87	Time: 1810	Surface	Analysis: GC/MS
Cross-Reference Sample:	26	Photo:	11

NOTES: - soft, sandy asphalt pavement at base of low backshore cliff

SAMPLE # 5	LOCATION: Espora Creek	SITE: 6B	ELEVATION: + shw
Date: 20-1-87	Time: 1820	Surface	Analysis: GC/MS
		Photos:	10, 12, 13

NOTES: - sandy asphalt pavement
- very soft and fresh in appearance

SAMPLE # 6	LOCATION: Espora Spit	SITE: 6C	ELEVATION: bfs
Date: 20-1-87	Time: 1830	Surface	Analysis: GC/MS
		Photo:	25

NOTES: - 15 m distance below lhws on bfs
- latex on fine-grained sediments, with some pb/cb
- = Blount's station MT 3-B

SAMPLE # 7 LOCATION: Espora Spit SITE: 6C ELEVATION: bfs
Date: 20-1-87 Time: 1835 Surface Analysis: GC/MS
Cross-Reference Sample: 30 Photos: 20, 21
NOTES: - soft sandy asphalt pavement on upper bfs
- 15 m east of samples #13 and 14

SAMPLE # 8 LOCATION: Espora Spit SITE: 6C ELEVATION: mhw
Date: 20-1-87 Time: 1840 Subsurface Analysis: GC/MS
Cross-Reference Samples: 9, 31
NOTES: - collected from middle of pavement, 2-4 cm depth
- soft sandy asphalt pavement on upper bfs

SAMPLE # 9 LOCATION: Espora Spit SITE: 6C ELEVATION: mhw
Date: 20-1-87 Time: 1845 Surface Analysis: GC/MS
Cross-Reference Samples: 8, 31
NOTES: - hard, weathered asphalt pavement surface
- sample taken from top 1 cm
- sandy, with some pebbles

SAMPLE # 10 LOCATION: Espora Spit SITE: 6D ELEVATION: + shw
Date: 20-1-87 Time: 1850 Surface Analysis: GC/MS
Cross-Reference Sample: 11 Photo: 30
NOTES: - very soft and fresh in appearance
- mousse; fine sediments
- sample taken from top 3 cm

SAMPLE # 11 LOCATION: Espora Spit SITE: 6D ELEVATION: + shw
Date: 20-1-87 Time: 1850 Surface Analysis: GC/MS
Cross-Reference Sample: 10 Photo: 30
NOTES: - weathered surface crust (top 1 cm) from same location as # 10

SAMPLE # 12 LOCATION: Espora Beach SITE: 6E ELEVATION: mhw
Date: 20-1-87 Time: 1245 Surface Analysis: GC/MS
Cross-Reference Samples: 34, 35
NOTES: - collected from upper beach face at mhw level
- hard pavement, fresh in appearance
- sandy pb-cb sediments

SAMPLE # 13 LOCATION: Espora Spit SITE: 6C ELEVATION: m-shw
Date: 20-1-87 Time: 1830 Surface Analysis: GC/MS
Cross-Reference Sample: 28 Photo: 22
NOTES: - very hard pavement; sample chiselled from top 3 cm
- sd-pb sediments on bfs 5 m above lhws and 5 m below shw level
- near # 14
- = Blount's station MT 3-B (see Fig. 3.4)

SAMPLE # 14	LOCATION: Espora Spit	SITE: 6C	ELEVATION: m-shw
Date: 20-1-87	Time: 1830	Surface	Analysis: GC/MS
Cross-Reference Sample: 29		Photo: 22	

NOTES: - very hard sd-pb pavement; sample chiselled from top 3 cm
- on upper bfs 5 m above lhws and 5 m below shw level
- near # 13; = Blount's station MT 3-B

SAMPLE # 15	LOCATION: Daniel Este	SITE: 2	ELEVATION: + shw
Date: 21-1-87	Time: 1530	Surface	Analysis: GC/MS
Cross-Reference Sample: 36			

NOTES: - at ENAP site 85-6
- soft, sandy narrow pavement at base of dunes
- very fresh (? "Metula")

SAMPLE # 16	LOCATION: Rio Oscar	SITE: 9	ELEVATION: + shw
Date: 22-1-87	Time: 1500	Surface	Analysis: GC/MS
Cross-Reference Sample: 40			

NOTES: - hard, narrow, brown sandy pavement
- buried, at base of dunes

SAMPLE # 17	LOCATION: Rio Oscar	SITE: 9	ELEVATION: + shw
Date: 22-1-87	Time: 1500	Surface	Analysis: GC/MS
Cross-Reference Sample: 41		Photo: 46	

NOTES: - buried, sand-pb asphalt pavement at base of dunes

SAMPLE # 18	LOCATION: Punta Baxa	SITE: 8	ELEVATION: + shw
Date: 22-1-87	Time: 1645	Surface	Analysis: GC/MS
Cross-Reference Sample: 42		Photo: 45	

NOTES: - hard, sandy asphalt pavement at base of dunes

SAMPLE # 19	LOCATION: Punta Baxa	SITE: 8	ELEVATION: + shw
Date: 22-1-87	Time: 1650	Surface	Analysis: GC/MS

NOTES: - surface of clump of vegetation eroded from dune edge

SAMPLE # 20	LOCATION: Punta Malvinas	SITE: 4	ELEVATION: + shw
Date: 22-1-87	Time: 1120	Surface	Analysis: GC/MS
Cross-Reference Sample: 38		Photo: 1	

NOTES: - hard pb-cb pavement
- on upper part of relict beach just below edge of vegetation
- at north radar tower (see Fig. 3.1)

SAMPLE # 21	LOCATION: Punta Malvinas	SITE: 4	ELEVATION: + shw
Date: 22-1-87	Time: 1120	Surface	Analysis: GC/MS
Cross-Reference Sample:	39	Photo:	1

NOTES: - soft, sandy pavement 1 m landward of #20 at edge of vegetation
- near north radar tower

SAMPLE # 22	LOCATION: Espora Beach	SITE: 6E	ELEVATION: ltt
Date: 23-1-87	Time: 1040	Surface	Analysis: GC/MS
		Photos:	40, 41

NOTES: - pb-cb soft, asphalt pavement
- many mussels
- 10 m seaward from junction of ltt with bfs

SAMPLE # 23	LOCATION: Espora Beach	SITE: 2	ELEVATION: ltt
Date: 23-1-87	Time: 1045	Surface	Analysis: GC/MS
Cross-Reference Sample:	43		

NOTES: - fine-grained sediments; "fresh" mousse
- 10 m seaward from # 22

SAMPLE # 24	LOCATION: Espora Spit	SITE: 6C	ELEVATION: bfs
Date: 23-1-87	Time: 1200	Surface	Analysis: GC/MS
		Photo:	26

NOTES: - latex crust on surface of pavement
- upper bfs near mhw
- 10 m distance below lhws

SAMPLE # 25	LOCATION: Banco Orange	SITE: 5	ELEVATION: + shw
Date: 20-1-87	Time: 1650	Surface	Analysis: th
Cross-Reference Sample:	1	Photos:	2, 3

NOTES: - narrow, sandy, brown pavement
- some shells and small pebbles
- = Blount's station MT 7 (see Fig. 3.2)

SAMPLE # 26	LOCATION: Espora Creek	SITE: 6B	ELEVATION: + shw
Date: 20-1-87	Time: 1810	Surface	Analysis: th
Cross-Reference Sample:	4	Photo:	11

NOTES: - sandy pavement at base of low dune cliff

SAMPLE # 27	LOCATION: Espora Creek	SITE: 6B	ELEVATION: m-shw
Date: 20-1-87	Time: 1820	Surface	Analysis: th
		Photos:	10, 12

NOTES: - pb-cb hard asphalt pavement
- on bfs above itz, 2m seaward of # 5

SAMPLE # 28 LOCATION: Espora Spit SITE: 6C ELEVATION: m-shw
Date: 20-1-87 Time: 1830 Surface Analysis: th
Cross-Reference Sample: 13 Photo: 22
NOTES: - sd-pb pavement
- on bfs, 5 m distance above lhws, 5 m below shw level
- very hard; sample chiselled from pavement

SAMPLE # 29 LOCATION: Espora Spit SITE: 6C ELEVATION: m-shw
Date: 20-1-87 Time: 1830 Surface Analysis: th
Cross-Reference Sample: 14 Photo: 22
NOTES: - very hard sd-pb pavement; sample chiselled from top 3 cm
- on bfs, 5 m distance above lhws, 5 m below shw level

SAMPLE # 30 LOCATION: Espora Spit SITE: 6C ELEVATION: bfs
Date: 20-1-87 Time: 1835 Surface Analysis: th
Cross-Reference Sample: 7 Photos: 20, 21
NOTES: - soft, sandy pavement
- collected from top 5 cm
- at edge of pavement on upper bfs near mhw

SAMPLE # 31 LOCATION: Espora Spit SITE: 6C ELEVATION: mhw
Date: 20-1-87 Time: 1840 Subsurface Analysis: th
Cross-Reference Samples: 8, 9
NOTES: - collected from 2 to 4 cm depth
- soft, sand pavement
- near mhw on upper edge of pavement on bfs

SAMPLE # 32 LOCATION: Espora Beach SITE: 6E ELEVATION: bfs
Date: 20-1-87 Time: 1850 Surface Analysis: th
Photo: 38
NOTES: - very soft, sd-pb pavement
- light brown mousse
- collected from pavement on upper bfs

SAMPLE # 33 LOCATION: Espora Beach SITE: 6E ELEVATION: bfs
Date: 20-1-87 Time: 1855 Surface Analysis: th
Photo: 38
NOTES: - non-pavement beach between areas of eroded, soft pavement
- adjacent to # 32

SAMPLE # 34 LOCATION: Espora Beach SITE: 6E ELEVATION: mhw
Date: 20-1-87 Time: 1900 Surface Analysis: th
Cross-Reference Samples: 12, 35
NOTES: - hard sd-pb pavement; fresh appearance
- collected from pavement on upper bfs at mhw
- duplicate of # 35

SAMPLE # 35	LOCATION: Espora Beach	SITE: 6E	ELEVATION: mhw
Date: 20-1-87	Time: 1900	Surface	Analysis: th

Cross-Reference Samples: 12, 34
NOTES: - hard sd-pb pavement; fresh appearance
- collected from pavement on upper bfs at mhw
- duplicate of # 34

SAMPLE # 36	LOCATION: Daniel Este	SITE: 2	ELEVATION: + shw
Date: 21-1-87	Time: 1530	Surface	Analysis: th

Cross-Reference Sample: 15
NOTES: - at ENAP site 85-6
- soft, sandy narrow pavement at base of dunes
- very fresh (? "Metula")

SAMPLE # 37	LOCATION: Punta Malvinas	SITE: 4	ELEVATION: + shw
Date: 22-1-87	Time: 1115	Surface	Analysis: th

NOTES: - hard pb-cb pavement
- collected from upper edge of relict beach
- near south radar tower (see Fig. 3.1)

SAMPLE # 38	LOCATION: Punta Malvinas	SITE: 4	ELEVATION: + shw
Date: 22-1-87	Time: 1120	Surface	Analysis: th

Cross-Reference Sample: 20 Photo: 1
NOTES: - hard pb-cb pavement on upper edge of relict beach
- at more northerly of 2 radar towers

SAMPLE # 39	LOCATION: Punta Malvinas	SITE: 4	ELEVATION: + shw
Date: 22-1-87	Time: 1120	Surface	Analysis: th

Cross-Reference Sample: 21 Photo: 1
NOTES: - soft, sandy pavement
- at edge of backshore vegetation; approx. 1 m landward of # 38

SAMPLE # 40	LOCATION: Rio Oscar	SITE: 9	ELEVATION: + shw
Date: 22-1-87	Time: 1500	Surface	Analysis: th

Cross-Reference Sample: 16
NOTES: - hard, narrow, sandy, brown pavement
- buried, at base of dunes

SAMPLE # 41	LOCATION: Rio Oscar	SITE: 9	ELEVATION: + shw
Date: 22-1-87	Time: 1500	Surface	Analysis: th

Cross-Reference Sample: 17 Photo: 46
NOTES: - buried, sd-pb pavement at base of dunes

SAMPLE # 42	LOCATION: Punta Baxa	SITE: 8	ELEVATION: + shw
Date: 22-1-87	Time: 1645	Surface	Analysis: th
Cross-Reference Sample:	18	Photo:	45

NOTES: - hard, sandy pavement at base of dunes

SAMPLE # 43	LOCATION: Espora Beach	SITE: 6E	ELEVATION: ltt
Date: 23-1-87	Time: 1045	Surface	Analysis: th
Cross-Reference Sample:	23		

NOTES: - fine-grained sediments
- mousse

SAMPLE # 44	LOCATION: Espora Beach	SITE: 6E	ELEVATION: ltt
Date: 23-1-87	Time: 1100	Surface	Analysis: th

NOTES: - surface latex crust with mousse below
- 10 m seaward of # 43

SAMPLE # 45	LOCATION: Espora Beach	SITE: 6E	ELEVATION: ltt
Date: 23-1-87	Time: 1110	Surface	Analysis: th

NOTES: - hard pb-cb pavement
- 20 m seaward of # 44

SAMPLE # 46	LOCATION: Espora Beach	SITE: 6E	ELEVATION: ltt
Date: 23-1-87	Time: 1115	Surface	Analysis: th

NOTES: - hard pb-cb pavement
- 20 m seaward of # 45

SAMPLE # 47	LOCATION: Espora Beach	SITE: 6E	ELEVATION: ltt
Date: 23-1-87	Time: 1130	Surface	Analysis: th

NOTES: - silt-sized sediments
- mousse
- 20 m seaward of # 46

SAMPLE # 48	LOCATION: Espora Beach	SITE: 6E	ELEVATION: ltt
Date: 23-1-87	Time: 1145	Surface	Analysis: th
		Photo:	42

NOTES: - pb-cb pavement
- very fresh mousse
- 50 m from low-tide level
- possible GC analysis

SAMPLE # 49	LOCATION: Espora Beach	SITE: 6E	ELEVATION: bfs
Date: 23-1-87	Time: 1145	Surface	Analysis: th
		Photo:	32

NOTES: - algae-covered sd-pb pavement, at base of bfs
- soft mousse with shells and pb
- very fresh appearance

SAMPLE # 50	LOCATION: Espora Beach	SITE: 6E	ELEVATION: bfs
Date: 23-1-87	Time: 1145	Surface	Analysis: th
Cross-Reference Sample:	51	Photos:	35, 36

NOTES: - soft, black, sandy pavement
- in mid-bfs
- collected from top 2 cm

SAMPLE # 51	LOCATION: Espora Beach	SITE: 6E	ELEVATION: bfs
Date: 23-1-87	Time: 1145	Subsurface	Analysis: th
Cross-Reference Sample:	50	Photos:	35, 36

NOTES: - collected from 2 to 5 cm depth
- soft, brown, silt-sd mousse

SAMPLE # 52	LOCATION: Espora Creek	SITE: 6B	ELEVATION: + shw
Date: 23-1-87	Time: 1230	Surface	Analysis: th
		Photos:	10, 14

NOTES: - hard, but malleable sd-pb pavement
- possible GC analysis

SAMPLE # 53	LOCATION: Espora Creek	SITE: 6B	ELEVATION: + shw
Date: 23-1-87	Time: 1230	Surface	Analysis: th
		Photos:	10, 15

NOTES: - soft, almost 100% oil
- 10 m south of sample # 52

SAMPLE # 54	LOCATION: Espora Creek	SITE: 6B	ELEVATION: + shw
Date: 23-1-87	Time: 1230	Surface	Analysis: th
		Photos:	10, 16

NOTES: - sd-pb pavement
- very hard, sample chiselled from pavement
- 10 m north of sample # 52

TABLE A.1 Summary of GC Samples

SITE	LOCATION				SEDIMENTS				OIL TYPE				CROSS-REFERENCE SAMPLE(S)
	ltt	bfs	m-shw	+shw	fine	sd	sd/pb	pb/cb	latex	mousse	soft asph.	hard asph.	
1 Banco Orange				x		x					x		25
2 Banco Orange	x					x					x		
3 Espora Marsh - A			x		x				x				
4 Espora Creek - B				x		x					x		26
5 Espora Creek - B				x		x					x		
6 Espora Spit - C		x					x		x				
7 Espora Spit - C		x				x					x		30
8 Espora Spit - C		x				x					x		9,31
9 Espora Spit - C		x				x						x	8,31
10 Espora Spit - D				x	x					x			11
11 Espora Spit - D				x	x						x		10
12 Espora Beach - E		x					x					x	34,35
13 Espora Spit - C		(x)	x				x					*	28
14 Espora Spit - C		(x)	x				x					*	29
15 Daniel Este				x		x					x		36
16 Rio Oscar				x		x						x	40
17 Rio Oscar				x			x					x	41
18 Punta Baxa				x		x						x	42
19 Punta Baxa				x		x					x		
20 Punta Malvinas				x				x				x	38
21 Punta Malvinas				x		x					x		39
22 Espora Beach - E	x							x			x		
23 Espora Beach - E	x				x					x			43
24 Espora Spit - C		x					x		x				

notes: (x) indicates that the sample was taken from the beach-face slope, but above the mean high water level;
* indicates that the sample had to be chiselled from the asphalt pavement.

TABLE A.2 Summary of Total Hydrocarbon Samples

SITE	LOCATION				SEDIMENTS				OIL TYPE				CROSS-REFERENCE SAMPLE(S)
	ltt	bfs	m-shw	+shw	fine	sd	sd/pb	pb/cb	latex	mousse	soft asph.	hard asph.	
25 Banco Orange				x		x					x		1
26 Espora Creek - B				x		x					x		4
27 Espora Creek - B			x					x				x	
28 Espora Spit - C		(x)	x				x					*	13
29 Espora Spit - C		(x)	x				x					*	14
30 Espora Spit - C		x				x					x		7
31 Espora Spit - C		x				x					x		8
32 Espora Beach - E		x					x				x		
33 Espora Beach - E		x					x				x		
34 Espora Beach - E		x					x					x	35
35 Espora Beach - E		x					x					x	34
36 Daniel Este				x		x					x		15
37 Punta Malvinas				x				x				x	
38 Punta Malvinas				x				x				x	20
39 Punta Malvinas				x		x					x		21
40 Rio Oscar				x		x						x	16
41 Rio Oscar				x			x					x	17
42 Punta Baxa				x		x						x	18
43 Espora Beach - E	x				x					x			23
44 Espora Beach - E	x				x				x				
45 Espora Beach - E	x							x				x	
46 Espora Beach - E	x							x				x	
47 Espora Beach - E	x				x					x			
48 Espora Beach - E	x							x		x			
49 Espora Beach - E		x					x				x		
50 Espora Beach - E		x				x					x		51
51 Espora Beach - E		x				x				x			50
52 Espora Beach - E				x			x					x	
53 Espora Beach - E				x		x					x		
54 Espora Beach - E				x				x				*	

notes: (x) indicates that the sample was taken from the beach-face slope, but above the mean high water level;
* indicates that the sample had to be chiselled from the asphalt pavement.

APPENDIX B: PUERTO ESPORA SAMPLE AND PHOTOGRAPH MAPS

Figure

B.1 Puerto Espora Index Diagram

B.2 Espora Marsh - Espora Creek Sample Locations

B.3 Espora Spit Backbeach Sample Locations

B.4 Espora Spit and Espora Beach Sample Locations

B.5 Espora Marsh - Espora Creek Photograph Locations

B.6 Espora Spit Backbeach Photograph Locations

B.7 Espora Spit and Espora Beach Photograph Locations

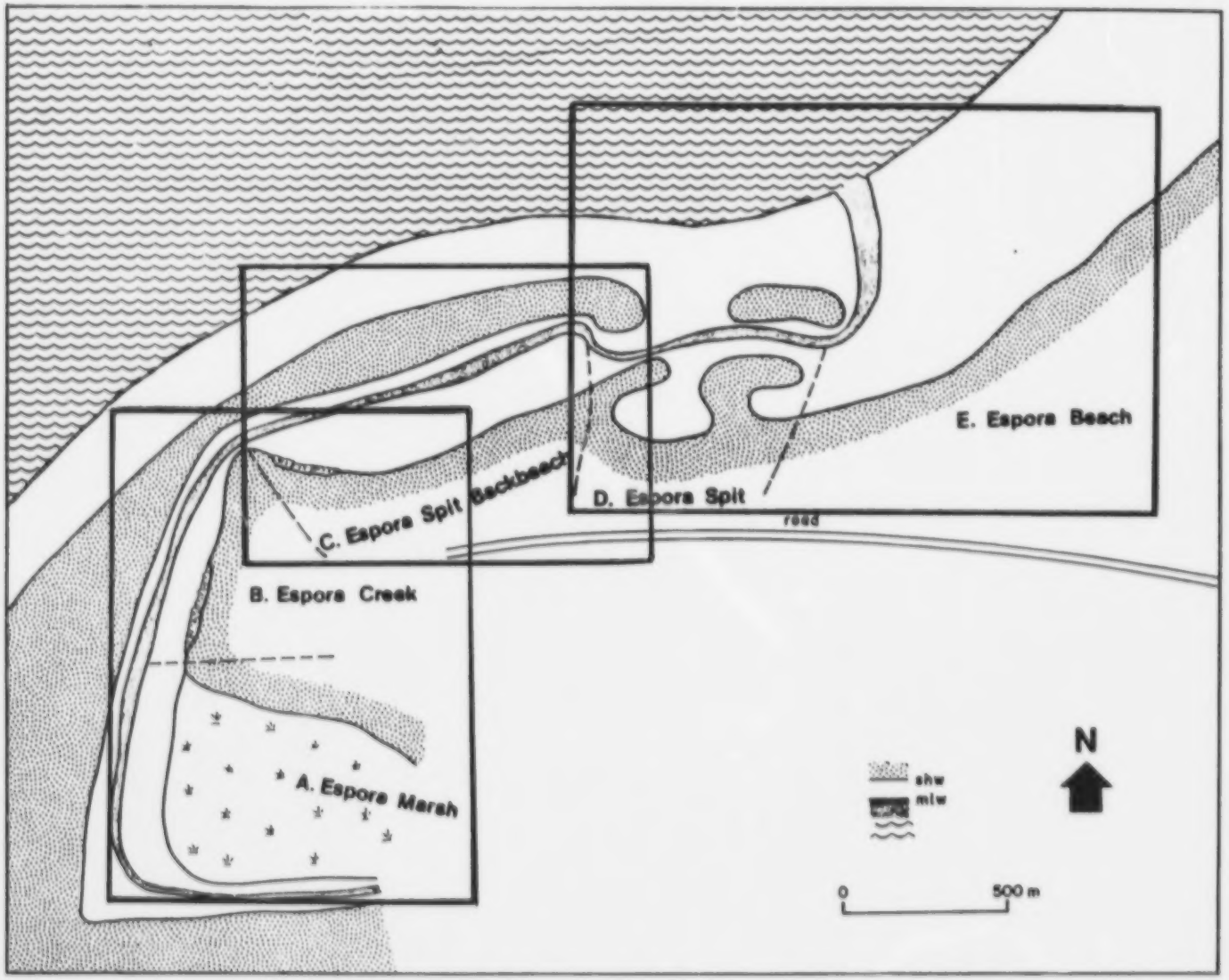


Figure B.1. Puerto Espora Index Diagram.

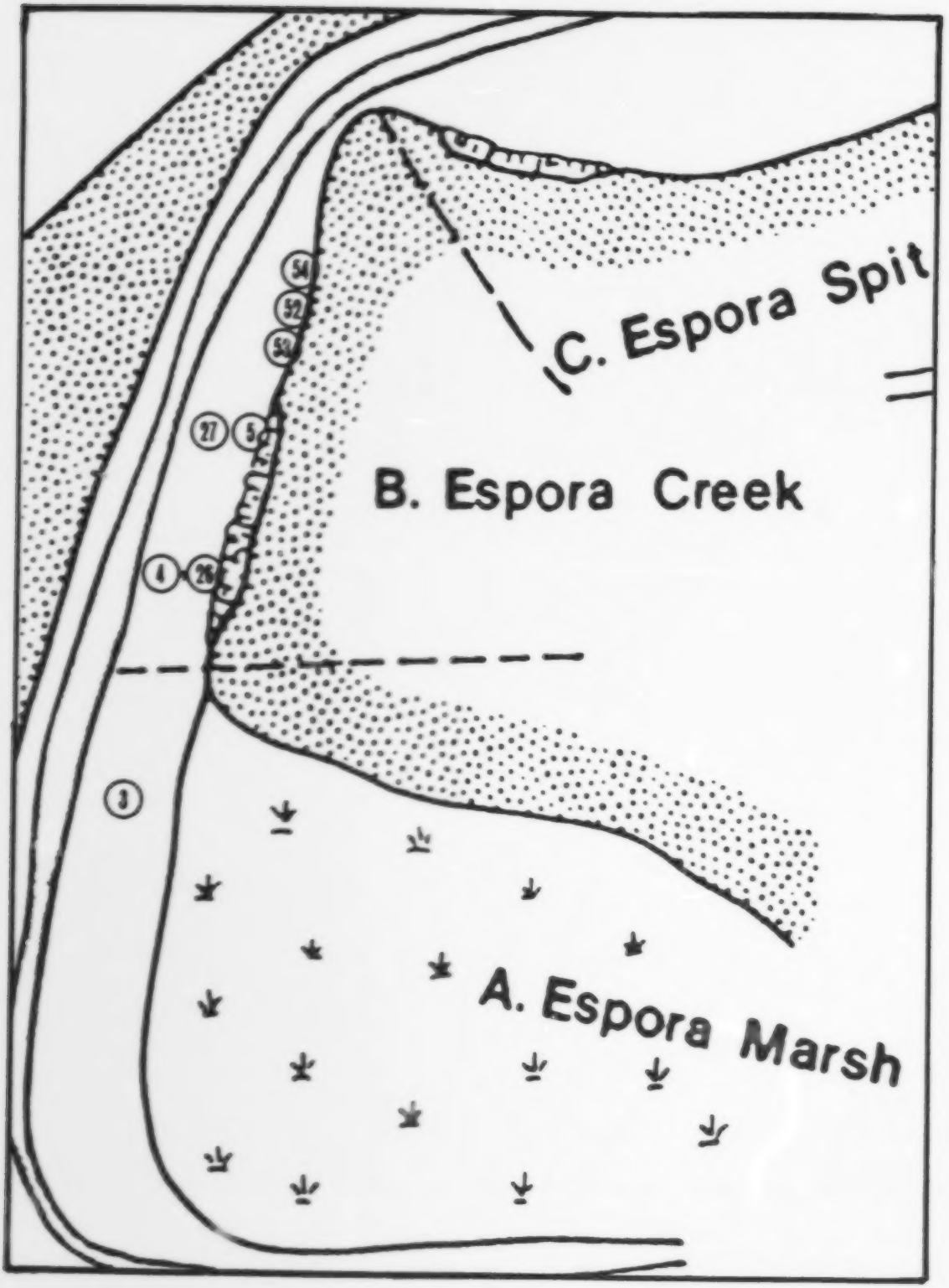


Figure B.2 Espora Marsh - Espora Creek Sample Locations.

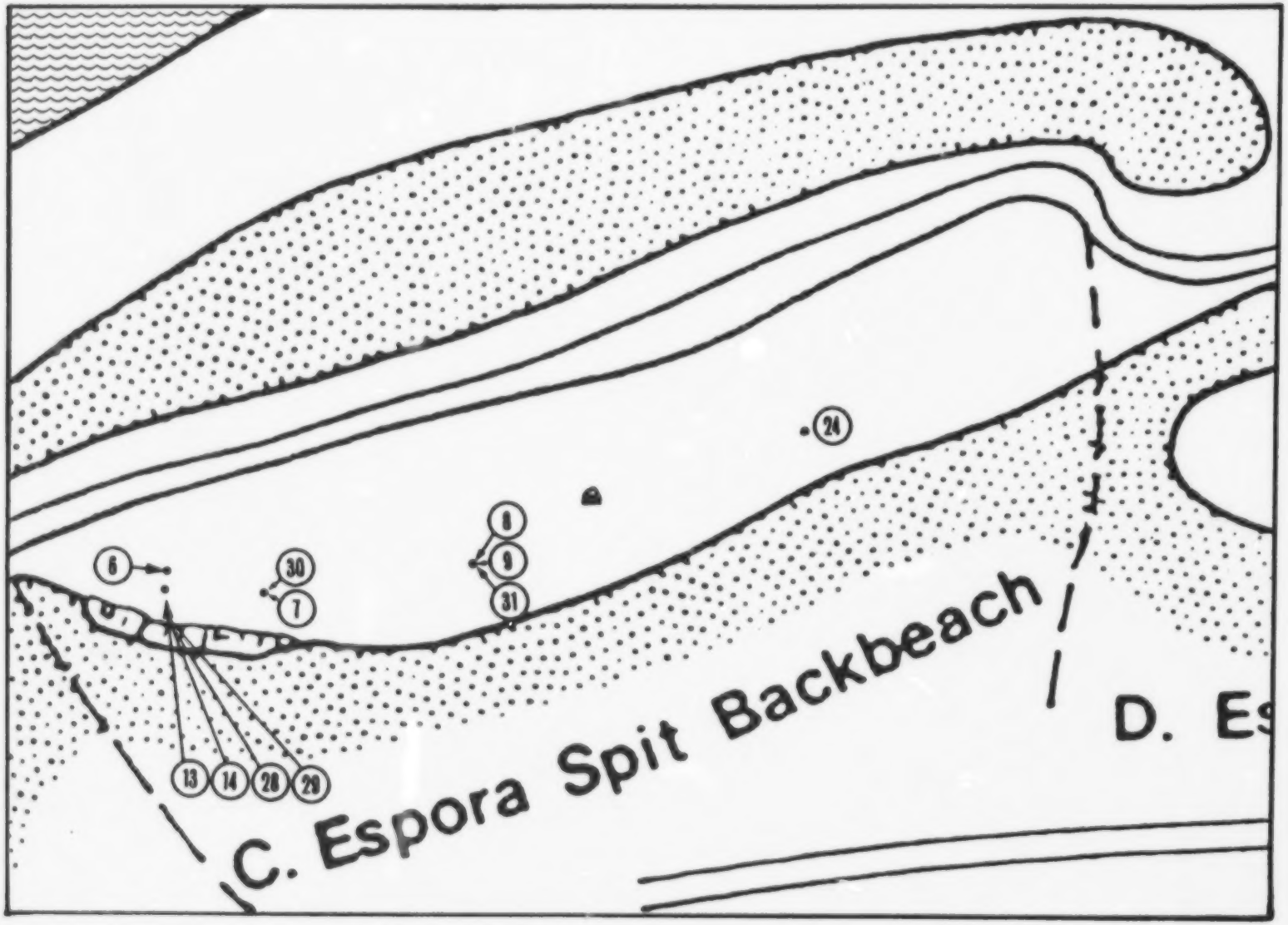


Figure B.3 Espora Spit Backbeach Sample Locations.

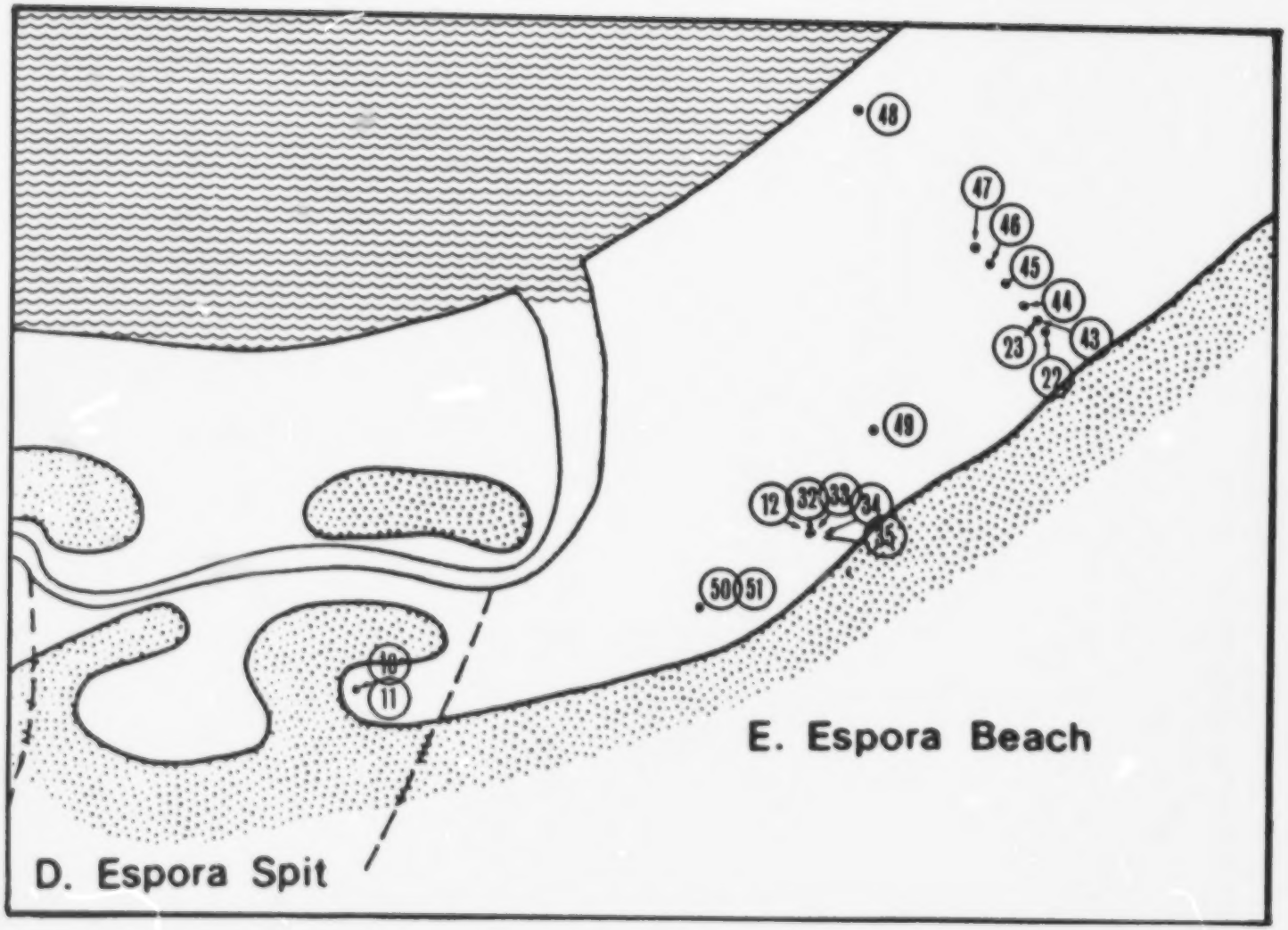


Figure B.4 Espora Spit and Espora Beach Sample Locations

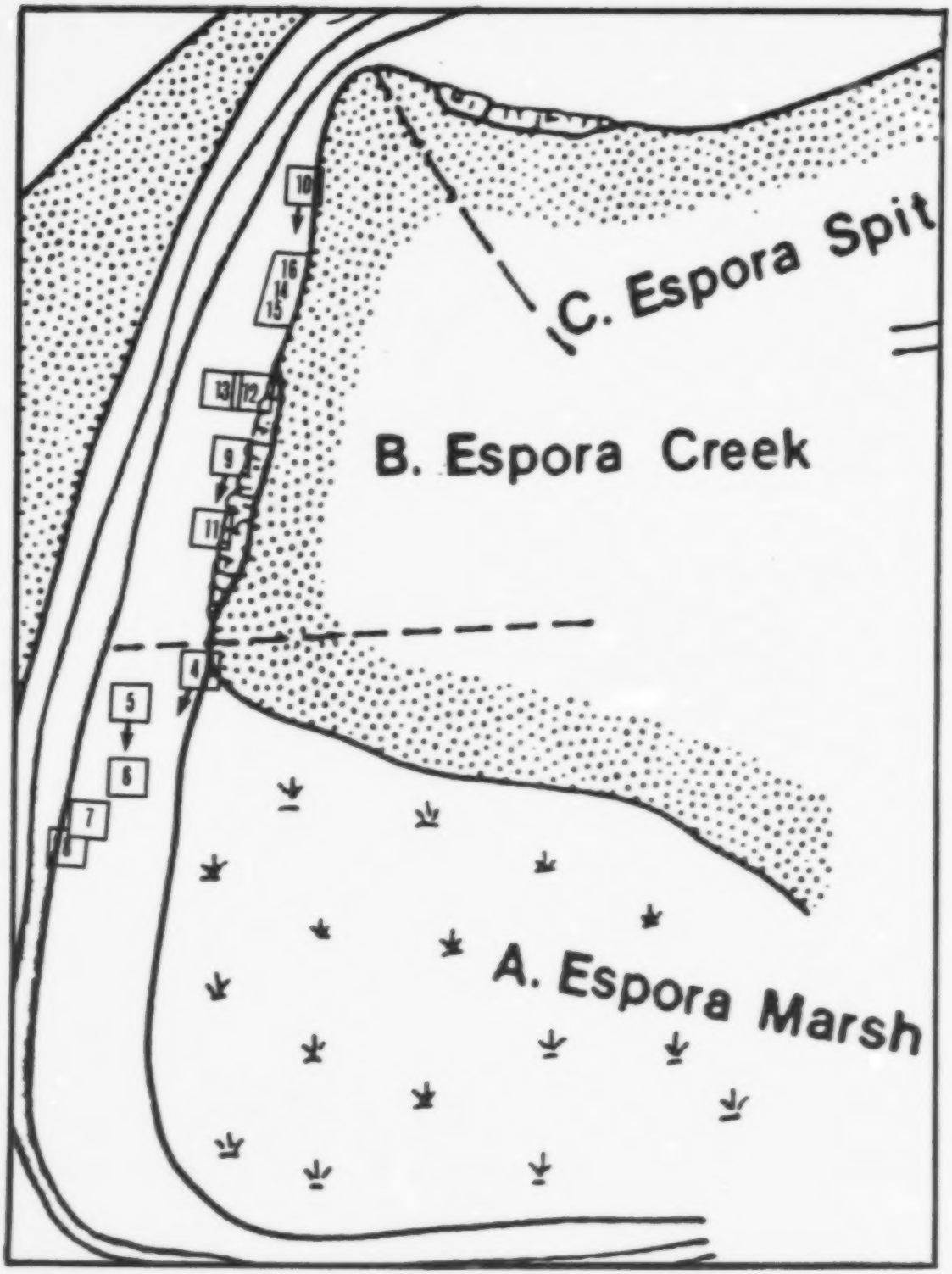


Figure B.5 Espora Marsh - Espora Creek Photograph Locations.

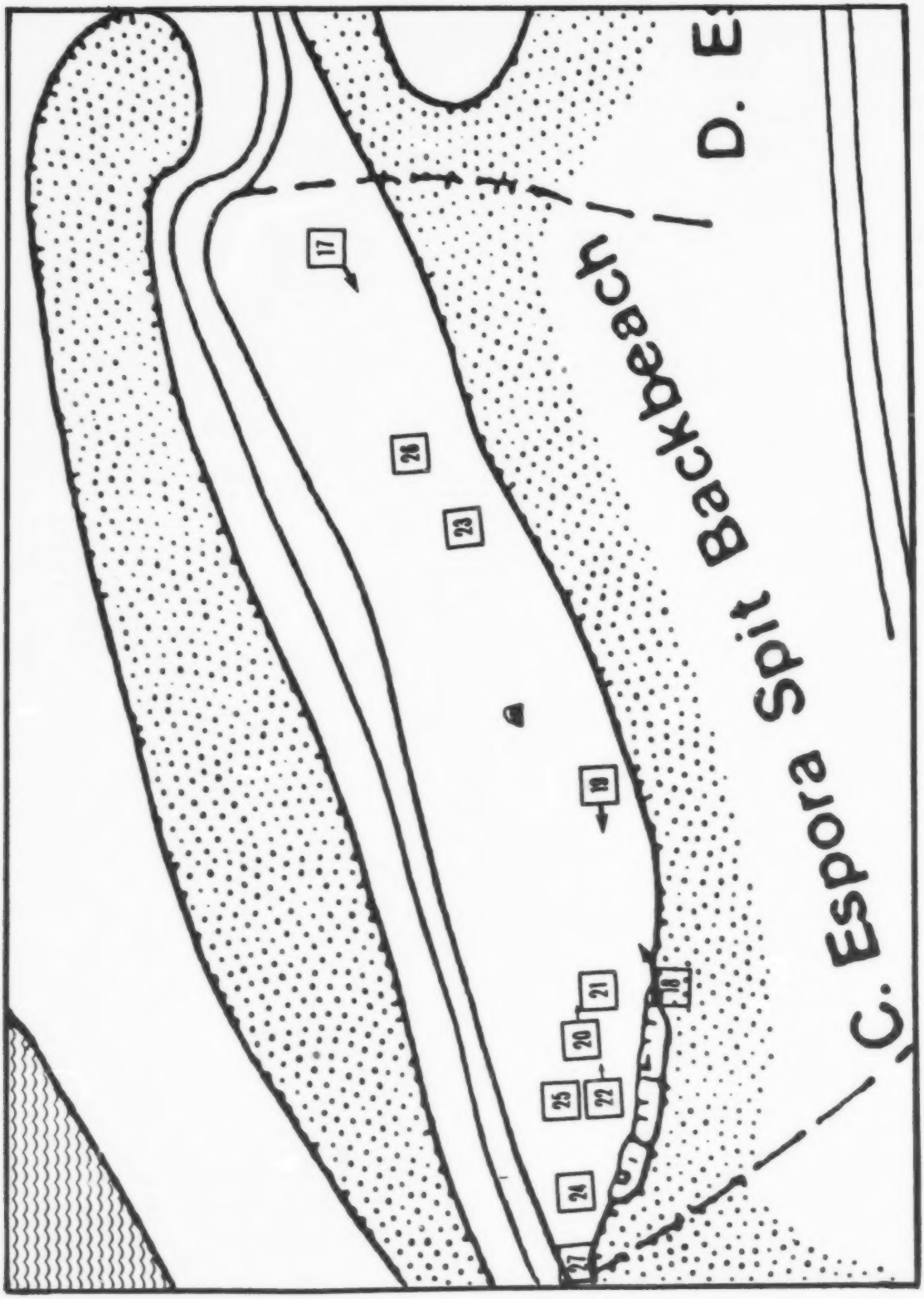


Figure B.6 Espora Spit Backbeach Photograph Locations.

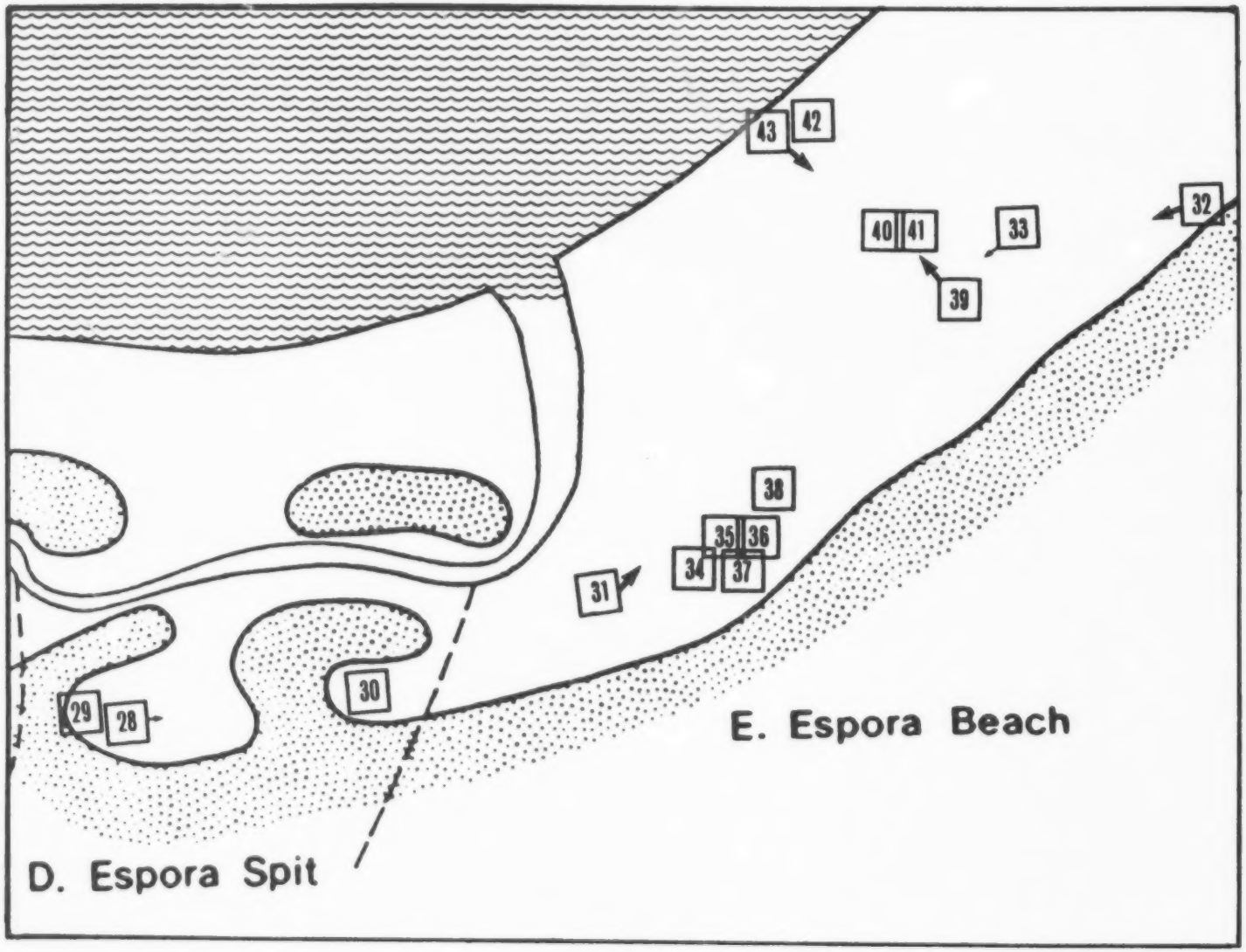


Figure B.7 Espora Spit and Espora Beach Photograph Locations.

Punta Malvinas:

1. 22-01-87 11:30
View from beach towards the crest of the relict ridge; single arrow locates samples #20 and #38; double arrow indicates the continuous soft pavement at the shw level (samples #21 and #39); note vegetation on relict bfs

Banco Orange:

2. 20-01-87 17:00
Discontinuous sandy pavement at shw level; pavement is buried on the landward margin by pb-cb sediments; lhws indicated by arrow

3. 20-01-87 17:00
Close-up of the shw pavement; samples #1 and #25

Espora Marsh:

4. 20-01-87 18:00
View of the ('West Estuary') marsh towards the south; person is standing at sample location #3; the shw level is marked by the seaweed line at left

5. 20-01-87 14:30
View to southeast towards the marsh showing the "latex" mat between the mhw and shw levels (the site of sample #3 is shown by the arrow - c.f. Photo 4)

6. 20-01-87 18:00
Close-up of sample #3; a thin oil layer ("latex") rests on fine-grained sediments in an area devoid of vegetation; the site is in the centre of a staked rectangular quadrat; scale is graduated in cm

7. 20-01-87 14:30
Marsh surface showing oiled small bush (Suaeda argentinensis) and bare patch where oil trapped by a Suaeda bush has smothered the Salicornia ambigua; both are "Metula" effects

8. 20-01-87 18:00
Healthy new Suaeda bushes (adjacent to Photo 7) that have grown since the "Metula" oiling; bare patch is located by arrow

Espora Creek:

9. 20-01-87 14:30
View to southeast at high tide towards marsh (arrow) illustrating the patchy, soft asphalt pavement between the mhw and shw levels

10. 23-01-87 12:30
View towards southeast 3 hours before high tide; person is sampling the shw pavement (samples #52, 53, and 54); the m-shw pebble-cobble pavement (samples #5 and 27) is marked by the two single arrows; the cross marks the location of Photo 11; double arrow locates the lhws

11. 20-01-87 18:15
Location of samples #4 and 26 from a sandy pavement at the shw located on Photo 10

12. 20-01-87 18:15
Sample #5 being collected from the sandy pavement just above the shw level; sample #27 was taken adjacent to the cardboard box from the pebble-cobble pavement

13. 20-01-87 14:20
Close-up of sample location #5

14. 23-01-87 11:45
Sample #52 at the shw level (Photo 10); hard pebble asphalt pavement

15. 23-01-87 11:45
Sample location #53 from the shw level (Photo 10); almost solid oil with no incorporated sediments

16. 23-01-87 11:45
Sample #54 at the shw level (Photo 10); a very hard pebble-cobble pavement from which the sample had to be chipped or chiselled

Espora Spit Backbeach:

17. 20-01-87 13:30
View towards the west, just before high tide; lower seaweed line marks the lhws; upper line (double arrow) marks the shw level; large rock (arrow) is also visible in Photo 18

18. 20-01-87 14:15
View to east at high tide from dune ridge; large rock still shows stain that records the shw level at the time of the "Metula" oiling

19. 20-01-87 14:15
View to west at high tide; the spit is located by the double arrows and the entrance to Espora Creek by the long arrow; Photo 18 was taken from the point marked by the white cross; the black cross locates Photo 24

20. 20-01-87 18:45
Upper edge of the asphalt pavement that has been eroded and undercut by backwash action; large rock located by the arrow (c.f. Photo 18); sample location #7 and #30; white arrow locates the lhws; scale is 25 cm

21. 20-01-87 18:45
Close-up of sample location #7 and 30

22. 20-01-87 18:40
Upper edge of pavement at the location of samples #13, 14, 28, and 29; the lhws is marked by the arrow; the pipe overhanging the backshore scarp is also visible on Photo 19; the large rock again provides a reference point

23. 23-01-87 12:20
View seaward of 'double-layer' pavement approx. 200 m east of the large rock; seaweed marks the lhws; scale is 25 cm

24. 20-01-87 14:20
Buried pavement at west end of Backbeach (see Photo 19); single pebble was removed and inverted to show fresh, black character of the subsurface oil; scale is marked in 5 cm intervals

25. 20-01-87 18:50
"Latex" oil mat (sample #6) from bfs in upper intertidal zone (below mhw); 15 m seaward from the sample location shown in Photo 22; lid of sample jar is 4 cm in diameter

26. 23-01-87 12:25
"Latex" mat or crust (sample #24) on pavement on the bfs, 15 m seaward from top edge of pavement

27. 20-01-87 14:25
"Latex" crust on soft oil near junction of Backbeach and Creek shoreline units; the latex surface has a veneer of fine sediments

Espora Spit:

28. 20-01-87 13:00
Upper edge of pb-cb pavement, above the mhw level; photo taken at high tide; scale is 25 cm in length

29. 20-01-87 13:00
Close-up of hard pb-cb pavement below shw level; a pebble was removed and inverted to show fresh, black character of the oil; scale is 25 cm in length

30. 20-01-87 19:30
Close-up of oil crust with sediment veneer (sample # 11) over a 2-cm thick layer of fresh, brown mousse (sample # 10), which oozed within a minute of the hole being dug; mousse overlies silt sediments; scale is graduated in cm; sample location is just below the shw level

Espora Beach:

31. 20-01-87 19:30
View to east at low tide from the west end of the beach unit; person is standing at the lhws

32. 23-01-87 11:30
View of pavement on western section of this beach at low tide; arrow marks lhws; Photo 33 is located by the cross; person is standing a sample location # 49

33. 23-01-87 11:35
Pavement in the middle of the bfs; arrow marks lhws; scale is 25 cm in length

34. 23-01-87 11:35
Close-up of upper edge of pb-cb pavement just below lhws, showing broken character of pavement edge; view seaward

35. 23-01-87 11:40
Sample locations # 50 and 51 on mid-bfs pavement just below lhws (arrow); the pavement is a soft, silt-sand, brown mousse with cobbles that have been forced into the soft, black surface crust

36. 23-01-87 11:45
Close-up of pavement at Photo 35 with cobble removed to show brown pavement oil; scale is 25 cm

37. 23-01-87 11:45
Close-up at same location as Photos 35 and 36 to illustrate the dark surface crust above the brown mousse

38. 20-01-87 19:40
Upper edge of pavement, 25 m to the east of Photo 35; sample # 32 was taken from this mousse pavement and # 33 (marked by the cross) from the sediments in the "clean" area between the pavement

39. 23-01-87 11:15
View seaward of ltt, at low tide; samples #22, 23, and 43 through 48 were collected on the gravel ridge in the center of the photo; person is standing at the junction of the bfs and ltt

40. 23-01-87 10:40
Sample # 22 from the cobble pavement on the inner edge of the ltt, 10 m seaward of the junction with the bfs

41. 23-01-87 10:40
Close-up of sample # 22; note presence of many mussels

42. 23-01-87 11:00
Close-up of sample # 48 collected from a pb-cb mousse pavement on the outer edge of the ltt, 50 m from the mlw line

43. 23-01-87 11:00
View landward from sample location # 48

Punta Baxa:

44. 22-01-87 16:45
View to the west, 5 km south of Punta Baxa 2 hours after high tide; lhws is shown by the double arrow; shw level marked by the single arrow

45. 22-01-87 16:50
Hard sd-pb pavement at the shw level; samples # 18 and 42

Rio Oscar:

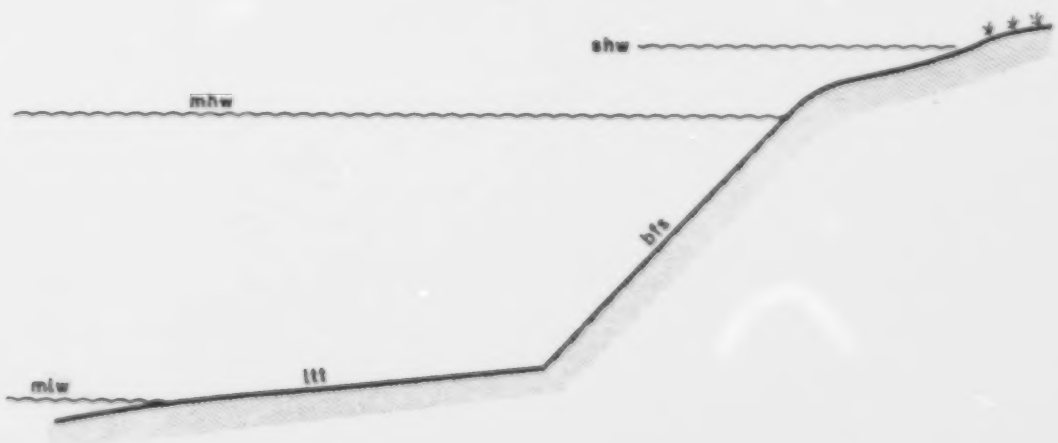
46. 22-01-87 15:00
Sd-pb pavement at the shw level; sample location for # 17 and 41 shown by the arrow: photo at high tide

ABBREVIATIONS:

bfs	beach-face slope: a section of the intertidal beach, usually the steepest part of the beach (see sketch below)
cb	cobble: sediments with a diameter between 64 and 256 mm
fine(s)	fine-grained sediments: diameter less than 0.06 mm
itz	intertidal zone: that section of the beach or shore between the mean-high water and mean-low water levels (see sketch below)
lhws	last high water swash: the elevation of the last high tide
ltt	low-tide terrace: a section of the intertidal beach in the lowest part of the intertidal zone, where present the low-tide terrace usually is nearly horizontal or has a very low slope (see sketch below)
mhw	mean high water: the mean high-tide elevation averaged over a long time period
mlw	mean low water: the mean low-tide elevation averaged over a long time period
m-shw or mhw-shw	mean to spring high water: the section of beach between the mean high-water elevation and the spring high-water elevation, usually characterized by a berm which has a lower slope angle than the beach-face slope (see sketch below)
pb	pebble: sediments with a diameter between 4 and 64 mm
sd	sand: sediments with a diameter between 0.06 and 4 mm
shw	spring high water: the elevation of the spring high tides, these are higher than the normal tides and occur twice monthly, at the new and full moons: the highest spring tides occur twice yearly at the spring and autumn equinoxes (NOTE: the "Metula" accident occurred just before a period of equinoctal spring tides so that much of the stranded oil was deposited on the backshore (q.v.) above the limit of normal wave activity at times of above-average water elevations)
+shw	above the spring high-water elevation

DEFINITIONS:

asphalt pavement	defined by Owens et al.(1986b) as a stable mixture of weathered hydrocarbons and sediments that, through time and physical changes, has formed a persistent and erosion-resistant deposit that is anchored to the beach surface
backshore	the section of beach above the mean high-water elevation that extends landward to the limit of storm-wave activity (c.f. supratidal zone)
berm	a section of the backshore (q.v.) beach above the beach face that is nearly horizontal or has a low slope angle and is above the limit of normal wave activity (see sketch below)
fetch	the area of open water over which waves can be generated by winds
latex	defined by Owens and Robson (1985) as a thin mat or layer of weathered oil that is malleable, usually coincident with fine-grained sediments and that is not mixed with sediments
mousse	a term sometimes used to describe an emulsion that has formed on the water surface by mixing with water; often a chocolate brown colour
supratidal zone	above the limit of the spring high-water level; this refers to the area above the intertidal zone, but it may include an area which is affected by marine processes during periods of storm-wave activity or of storm surges



Sketch illustrating relationship between across-shore zones and terminology.